National Aeronautics and Space Administration

HIGH-END COMPUTING CAPABILITY PORTFOLIO

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NASA Advanced Supercomputing Division

June 10, 2020

HECC Completes Annual Building Maintenance

- HECC facilities engineers worked with Center Operations Directorate (Code J) to plan, coordinate, and conduct the annual maintenance activities for three NAS facilities housing HECC resources, including numerous repairs and maintenance of key components of the facilities.
- The main NAS facility (N258) and the modular supercomputing sites (R&D088, R&D099) maintenance work required complete building power shutdowns, with Pleiades, Electra, Aitken, and storage system equipment powered off.
- Activities completed during the maintenance period include:
  - Cleaned the condenser tubes of the N258 chillers.
  - Cleaned and tested 480V power switchgear and circuit breakers.
  - Cleaned the N258 computer room sub-floor.
  - Tested all N258 fire suppression systems.
  - Replaced belts and filters on the building and computer room air handlers and the RUPS air intakes.
  - Cleaned the R&D088 roof-top adiabatic coolers.
  - Inspected the internal connections of R&D088 pin-and-sleeve connectors to confirm electrical integrity.
  - Cleaned and tightened R&D088-099 panelboard electrical connections.

IMPACT: Preventative maintenance of HECC cooling systems and electrical distribution eliminates downtime caused by an aging infrastructure, yielding more computer uptime for agency users.

A heating, ventilation, and air conditioning (HVAC) technician cleaning the condenser tubes on one of the chillers in building N258, the NASA Advanced Supercomputing facility at Ames Research Center. *Chris Tanner, NASA/Ames*

Main Computer Room Power Restored After Circuit Breaker Failure

- At the completion of the Building N258 annual maintenance on May 15 (see slide #3), Code J electricians were restoring power to the main computer floor when a 1,200-amp feeder breaker experienced an arc flash, destroying the breaker and knocking out power to the building's network, storage, and nearly half the compute resources.
- A failure in the closing spring mechanism resulted in an arc between the breaker's electrical contacts before the contacts met.
  - The air in the breaker ionized as the contacts came close to each other, allowing a large amount of current to flow within the breaker, resulting in an electrical explosion of sparks, heat, and concussive forces.
  - In normal operation, the closing spring forces the contacts together fast enough that an arc cannot be established. The electrician, dressed in a Cat 4 Arc Flash Suit, was unharmed.
- Code J and NAS facility engineers repaired the electrical switchgear by cleaning the busbars and switchgear interior of carbon soot, measuring the insulation resistance of the load wires, inspecting each load-side power distribution unit, and sourcing and installing new breakers and accessories.
- Power was restored to the main computer room on May 19, 2021.

IMPACT: By restoring power in four days after a circuit breaker arc flash caused a very significant electrical failure, NAS and Ames facility engineers minimized the downtime of HECC resources.

At left, the 1200A circuit breaker that experienced the arc flash. The 1200A breaker on the right was also replaced, as it experienced collateral damage from the arc flash. *Chris Tanner*, *NASA Ames*

R&D088 Electrical Upgrades Address Poor Power Quality

- In 2020, incoming power quality issues from the utility feeding Ames Research Center (ARC) resulted in three power outages of the R&D088 module, which houses the Electra supercomputer.
  - Voltage sags (a reduction in voltage for a short time) of 60% of nominal voltage for four to six cycles occurred two to three times a year.
  - Each power outage was caused by a single-phase voltage sag from the utility, causing both the main and feeder circuit breakers for the module to trip for a ground fault.
  - Inspection of the electrical distribution determined there were no ground fault conditions, and the trips were categorized as “nuisance trips.”
- During the annual maintenance shutdown (see slide #3), NAS facility engineers teamed with breaker and computer manufacturers and Code J engineers and determined that the phase-to-neutral configuration of computer power supplies caused a breaker trip unit to calculate a ground fault current large enough to trip the breaker during a voltage sag.
- Code J and NAS engineers reconfigured the breaker settings and installed a current transformer on the ground wires to measure actual ground current, which eliminates nuisance trips and improves the uptime of HECC resources.

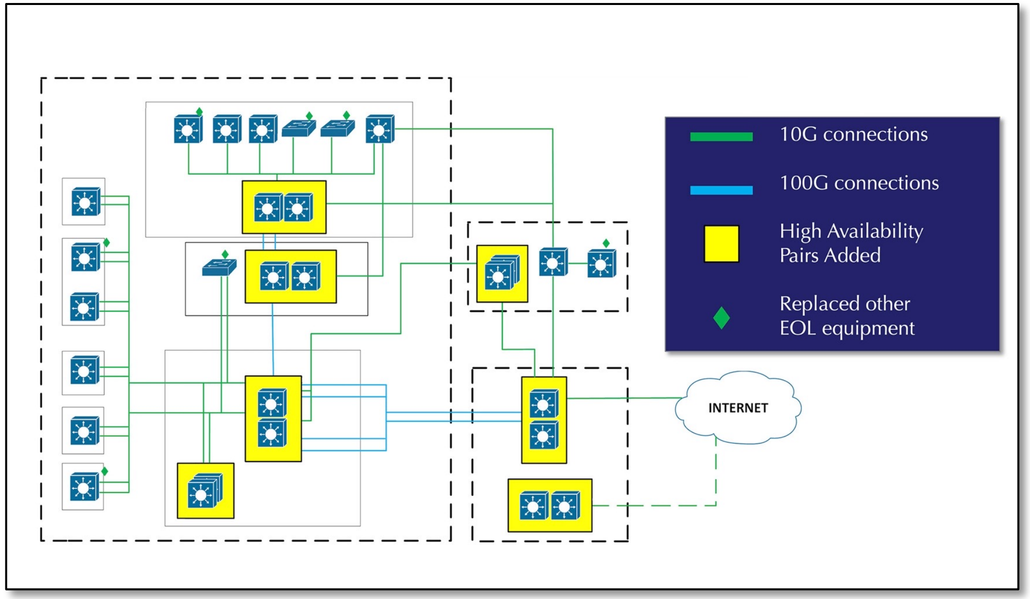
IMPACT: A robust electrical system that can ride-through poor incoming power quality results in a more reliable supercomputer environment and higher system availability for HECC users.

One of the current transformers installed on the ground wires for the modules at module R&D088, which houses the Electra supercomputer. *Chris Tanner, NASA/Ames*

Networks Team Deploys Enhanced NASLAN Infrastructure

- The HECC Networks team completed the upgrade to the NASLAN network. The main goal of the network infrastructure update was to establish high availability and other network enhancements.
- Objectives of this year-long project were:
  - **High availability**: removed multiple single points of failure by deploying switch pairs where the primary automatically fails over to the backup.
    - Enables router/switch firmware upgrades without impacting the network.
  - **Increased bandwidth:** replaced multiple saturated 10-Gbps links with 100 Gbps links.
  - **Network Equipment Refres**h: replaced equipment that was end-of-life.
  - **Improved Network Design:** Installed dedicated switches for NASA's Mission Assurance System (MAS), created cleaner separation between routed and switched infrastructure to simplify day-to-day network maintenance, and improved security policies defining permitted traffic.
  - **Improved Power Resiliency**: Connected critical network devices with redundant power supplies to different power distribution units with uninterruptible power supply backup.

IMPACT: Network enhancements improve reliability and user access to HECC supercomputing systems.

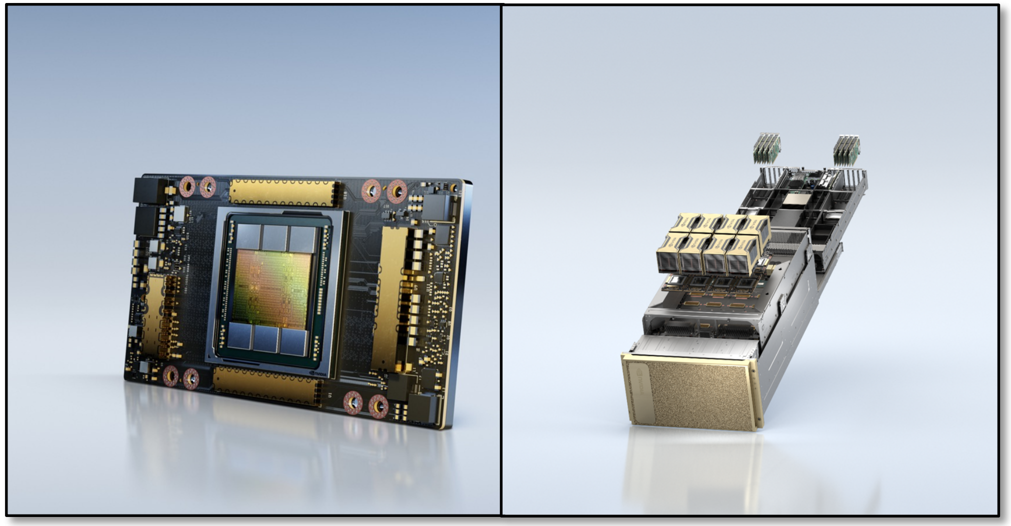


High-level diagram of the new NASA Advanced Supercomputing facility network architecture, *HECC Network Team*.

HECC Selects Vendor for Pathfinding Test Systems

- As part of its FY21 plan for pathfinding activities, the HECC project is acquiring small test systems for advanced architectures. After receiving bids through a Request for Quote process, two systems were selected:
  - An HPE Apollo 6500 Gen10 system with two nodes, each with eight NEC Vector Engine accelerator cards.
  - An HPE Apollo 6500 Gen10 Plus system with two nodes, each with eight NVIDIA A100 high-power GPUs.
- The selection of the architectures was based on earlier evaluation of non-x86 single-node systems with the following characteristics:
  - Systems that use high-bandwidth memory (HBM), which may address the very common memory-bandwidth performance bottlenecks seen for NASA's high-end computing applications.
  - Systems that have special architectures, such as wide-vector processing units (VPUs) and general-purpose graphic processing units (GPGPUs), to substantially improve numerical operations.
- The test systems will be used by a select number of staff and users to conduct in-depth analysis of NASA-relevant benchmarks and applications.

IMPACT: Identifying the most cost-effective computing resources for NASA's high-performance computing requirements ensures that HECC maximizes the science and engineering impact of its procurement budget.



An NVIDIA DGX A100 server (right) with eight A100 GPUs (left). Each GPU has 40 or 80 GB high-bandwidth memory (HBM) and is capable of 9.7 teraflops double precision.
Images courtesy of NVIDIA

Merope Supercomputer Retired After 5 Years of Service

- The Merope supercomputer, a cluster comprised of repurposed Intel Xeon X5670 (Westmere) processors that were once part of the Pleiades supercomputer, was decommissioned on May 12, 2021. The system was gracefully shut down during the annual facility maintenance period (see slide #3).
- The Westmere racks were originally installed in Pleiades on February 3, 2011 and performed continuously until they were moved to Merope in January 2017.
- The Merope racks were installed in an auxiliary building at Ames when newer hardware was procured for Pleiades.
  - The Westmere racks consisted of 1,792 compute nodes, each with two six-core Intel Xeon X5670 processors.
  - The total potential SBU* production work on Merope was equal to the potential SBU production work on one Apollo 9000 rack (AMD Rome nodes) on the Aitken supercomputer.
- Approximately 50 Knowledge Base articles were updated to reflect Merope's decommissioning, and the Merope resource page was replaced with a short summary on the HECC Legacy Systems page.

* *1 SBU represents the work that can be done in 1 hour on a Pleiades Broadwell 28-core node.*

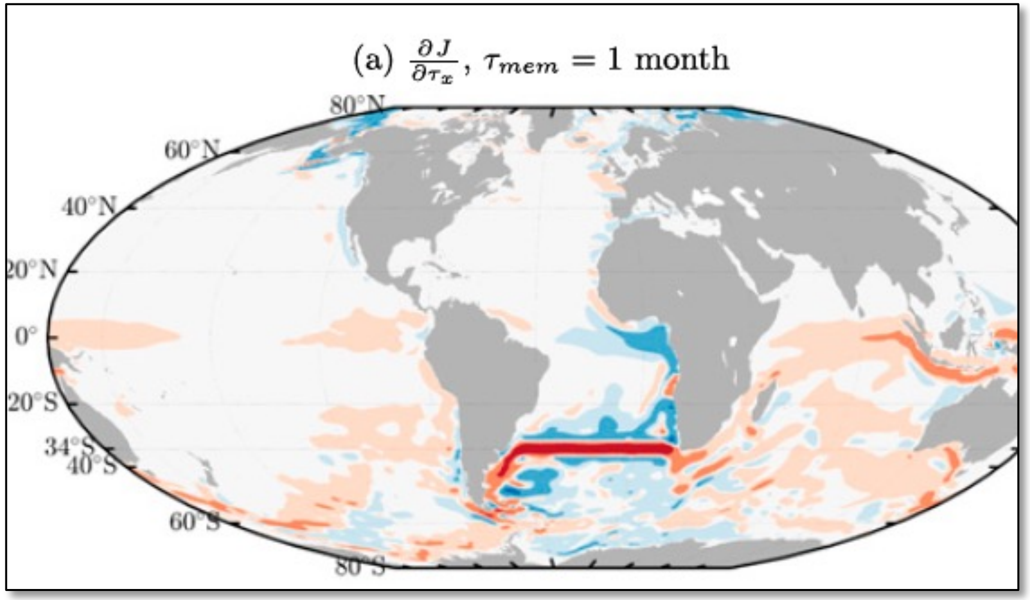
IMPACT: HECC continually examines the cost effectiveness of operating its assets. After a careful analysis, HECC determined that the Merope system was no longer practical to operate and support. This will reduce operations cost and allow budget for new hardware.

A row of Merope racks in building 233A on the NASA Ames campus. The system was made up of 1,792 nodes. The system delivered 10,150,146 SBUs during its lifetime. *Building 233A NASA/Ames*

Application Experts Improve Performance of Ocean Code

- As a follow on to work reported in January 2021, the HECC Applications Performance and Productivity (APP) team improved the adjoint workflow of the Massachusetts Institute of Technology General Circulation Model (MITgcm) by 2 to 4 times.
  - The adjoint workflow allows scientists to efficiently determine how one system variable (e.g., ocean surface temperature) depends on a separate control variable (e.g., atmospheric surface wind speed).
  - Being able to determine causal relationships helps scientists answer important questions about the ocean's highly complex system.
- The adjoint workflow is a major contributor to filesystem contention on Pleiades. The APP team used the "iot" tool from I/O Doctors, LLC to determine both the location and the cause of the filesystem contention.
  - With this knowledge, the team modified over 100 application source and configuration files with the goal of limiting interaction with the filesystem.
  - Where limiting filesystem interaction was not feasible, the team made the interaction more efficient by limiting the number of times a file is opened and closed.
  - The APP team took a further step to perform a sweep for latent code bugs, which revealed 11 issues that could impact numerical results.

IMPACT: Performance improvements for heavily used codes such as MITgcm not only reduce the time to solution for the user's workflow, but also result in system resources being available for other work.

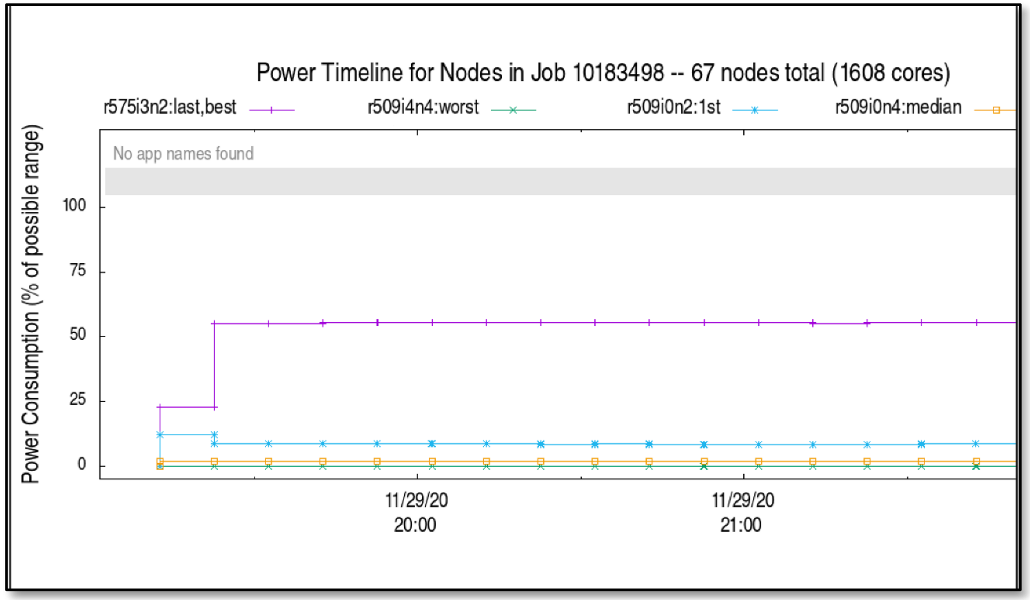


Atmospheric origins of variability in the South Atlantic meridional overturning circulation, using MITgcm fit to observational data.
Timothy Smith, Patrick Heimbach, Institute for Computational Engineering and Sciences, The University of Texas at Austin

Applications Team Finds and Fixes Inefficient Jobs

- HECC's Application Performance and Productivity team recently helped three users whose jobs were identified by a new feature of the weekly job power usage report.
  - The report now integrates the power usage samples over time on each node and then reports jobs that have some nodes that don't seem to be doing any computation.
  - When used in conjunction with a graphing tool, the power usage information can show when nodes aren't using any power over significant periods of time.
- After issues were identified by the tool, APP team members worked with users to develop solutions.
  - One user had a syntax error in his GNU Parallel script that led to some nodes of the job going unused. APP worked with the user to fix the script and to introduce hyperthreading into the job. The result was an efficiency improvement of 4.65 times.
  - After being notified by the APP team that nodes in their job weren't being used, a second user changed the job resource requests from 10 nodes to 3 nodes.
  - When APP investigated jobs for a third user, they found that their automatic validation jobs weren't working after a PBS version change. The problem was traced to an issue with PBS. A workaround was implemented, and the automatic validation runs resumed.

IMPACT: Ongoing performance monitoring of compute resources enables HECC experts to improve both user turnaround times and overall system utilization.



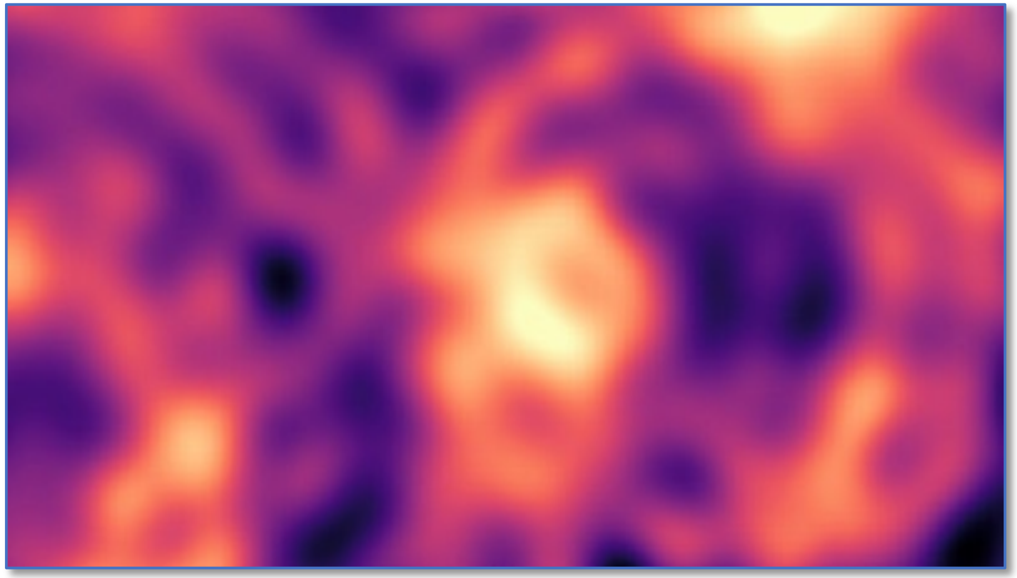
A timeline generated by the job power usage report's graphing tool shows power usage by different nodes in a job. In this case, it indicates that at least two of the nodes in the job don't seem to be doing anything.

Imaging the Solar Interior: Emerging Active Regions *

- With help from HECC resources, heliophysics experts at New Jersey Institute of Technology (NJIT) Bullet are laying the groundwork for a Coronal Mass Ejection (CME) warning system.
- Using velocity data from NASA's Solar Dynamics Observatory (SDO) to compute images of the solar interior, the scientists are tracking the formation of active regions on the Sun, the first step in building a reliable space weather forecasting tool.
  - Using images from SDO'S Helioseismic and Magnetic Imager (HMI), the team observes time-dependent structures that they interpret as rising magnetic flux, which forms active regions on the Sun's surface.
  - The team uses HMI maps of the line-of-sight velocity to produce images of the solar interior, focusing on regions between 40,000 and 70,000 kilometers from the Sun's surface; the heliophysics community has hypothesized that magnetic structures form in this area.
- The team, led by NJIT's Alexander Kosovichev, also developed a technique to associate changes in magnetic structure to local conditions, such as density and magnitude of the magnetic field.
- HECC resources and code optimization expertise enabled the NJIT scientists to save three months in processing images of one active region, using 1,000 processors on Pleiades vs. a desktop system.

** HECC provided supercomputing resources and services in support of this work.*

IMPACT: The availability of HECC resources and code optimization services greatly accelerates processing images of the solar interior obtained from the Solar Dynamics Observatory—a critical step in developing a space weather forecasting tool.



A travel time map of Active Region 12772 several hours before the magnetic flux has emerged on the Sun's surface. Redder areas correspond to a shorter travel time, and the strongly negative region is interpreted as the rising magnetic flux (in larger picture). *John Stefan, New Jersey Institute of Technology*

CFD Support for Enabling Commercial Supersonic Flight *

- NASA's X-59 Quiet SuperSonic Technology (QueSST) is an advanced low-boom aircraft concept that will be used to emulate and test the noise generated by future supersonic transport designs. The project is a partnership between NASA and Lockheed Martin, with the goal is to develop an aircraft design that doesn't create an objectionable sonic boom on the ground during supersonic flight.
- Using the computational fluid dynamics (CFD) tools Cart3D and the Launch Ascent and Vehicle Aerodynamics (LAVA) flow solver, researchers in the NASA Advanced Supercomputing (NAS) Division performed rapid analyses of new designs to predict loudness values and verify the X-59's supersonic performance.
- Both Cart3D and LAVA have been shown to produce very similar noise prediction at ground level. Since no experimental data has been obtained for the X-59—which is currently being constructed at Lockheed's Skunk Works facility in Palmdale, CA—it has been crucial to verify CFD solutions across as many solvers as possible to build confidence in the predictions.
- Both NAS-developed codes are also being used to develop a flight planning tool to predict how the control surfaces of the aircraft should be manipulated to achieve target loudness levels, which will require running hundreds or thousands of large-scale CFD simulations over the next few years.

IMPACT: The design validation and flight prediction database produced for the X-59 project supports NASA's Innovation in Commercial Supersonic Aircraft strategic goals for the Aeronautics Research Mission Directorate.

A flow visualization of NASA's X-59 supersonic, low-boom aircraft concept run the Pleiades supercomputer using the Launch Ascent and Vehicle Aerodynamics (LAVA) flow solver. Red and blue represent high and low pressure, respectively; the symmetry plane—which bisects the vehicle along its center line—is colored by Mach number. *James Jensen, NASA/Ames*

** HECC provided supercomputing resources and services in support of this work.*

Papers

- "**On the Rate of Energy and Deposition by an Ion Ring Velocity Beam**," Y. Omelchenko, et al., Physics of Plasmas, vol. 28, issue 5, published online May 3, 2021. *
https://aip.scitation.org/doi/abs/10.1063/5.0046309
- "**TESS and HARPS Reveal Two Sub-Neptunes around TOI 1062**," J .Otegi, et al., arXiv:2105.01945 [astro-ph.EP], May 5, 2021. *
https://arxiv.org/abs/2105.01945
- "**Projected Land Ice Contributions to Twenty-first-century Sea Level Rise**," T. Edwards, et al., Nature, vol. 593, May 5, 2021. *
https://www.nature.com/articles/s41586-021-03302-y...
- "**Latitude Variation of Flux and Impact Angle of Asteroid Collisions with Earth and the Moon**," D. Robertson, P. Pokorny, M. Granvik, L. Wheeler, C. Rumpf, The Planetary Science Journal, vol. 2, no. 3, May 6, 2021. *
https://iopscience.iop.org/article/10.3847/PSJ/abefda/meta
- "**Building Robust AGN Mock Catalogs to Unveil Black Hole Evolution and for Survey Planning**," V. Allevato, et al., arXiv:2105.02883 [astro-ph.CO], May 6, 2021. *
https://arxiv.org/abs/2105.02883
- "**Surface Manifestation of Stochastically Excited Internal Gravity Waves**," D. Lecoanet, et al., arXiv:2105.04558 [astro-ph.SR], May 10, 2021. *
https://arxiv.org/abs/2105.04558

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Papers (cont.)

- "**Multiscale Nature of the Magnetotail Reconnection Onset**," M. Sitnov, T. Motoba, M. Swisdak, Geophysical Research Letters, May 11, 2021. *
  https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2021GL093065
- "**Discovery and Confirmation of the Shortest Gamma Ray Burst from a Collapsar**," T. Ahumada, et al., arXiv:2105.05067 [astro-ph.HE], May 11, 2021. *
  https://arxiv.org/abs/2105.05067
- "**Building and Maintaining a Solar Tachocline through Convective Dynamo Action**," L. Matilsky, J. Toomre, arXiv: 2105.05412 [astro-ph.SR], May 12, 2021. *
  https://arxiv.org/abs/2105.05412
- "**Planets Hunters TESS III: Two Transiting Planets around the Bright G Dwarf HD 152843**," N. Eisner, et al., Monthly Notices of the Royal Astronomical Society, published online May 12, 2021. *
  https://academic.oup.com/mnras/advance-article-abstract/doi/10.1093/mnras/stab1253/6274703
- "**Photospheric Prompt Emission from Long Gamma Ray Burst Simulations – I. Optical Emission**," T. Parsotan, D. Lazzati, arXiv:2105.06505 [astro-ph.HE], May 13, 2021. *
  https://arxiv.org/abs/2105.06505
- "**TOI-1231 b: A Temperate, Neptune-sized Planet Transiting the Nearby M3 Dwarf NLTT 24399**," J. Burt, et al., arXiv:2105.08077 [astro-ph.EP], May 17, 2021. *
  https://arxiv.org/abs/2105.08077

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Papers (cont.)

- "**Transport of Nitric Oxide via Lagrangian Coherent Structures into the Top of the Polar Vortex**," V. L. Harvey, et al., Journal of Geophysical Research: Atmospheres, vol. 126, issue 11, May 17, 2021. *
  https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020JD034523
- "**TKS X: Confirmation of TOI-1444b and a Comparative Analysis of the Ultra-short-period Planets with Hot Neptunes**," F. Dai, et al., arXiv:2105.08844 [astro-ph.EP], May 18, 2021. *
  https://arxiv.org/abs/2105.08844
- "**TIC 172900988: A Transiting Circumbinary Planet Detected in One Sector of TESS Data**," V. Kostov, et al., arXiv:2015.08614 [astro-ph.EP], May 18, 2021. *
  https://arxiv.org/abs/2105.08614
- "**Linking Global Terrestrial CO2 Fluxes and Environmental Drivers: Inferences from the Orbiting Carbon Observatory 2 Satellite and Terrestrial Biospheric Models**," Z. Chen, et al., Atmospheric Chemistry and Physics, European Geosciences Union, published online May 18, 2021. *
  https://hal.archives-ouvertes.fr/hal-03229030/
- "**Computer Simulation of Microstructure Development in Powder-Bed Additive Manufacturing with Crystallographic Texture**," J. Pauza, W. Tayon, A. Rollett, Modeling and Simulation in Materials Science and Engineering, published online May 20, 2021. *
  https://iopscience.iop.org/article/10.1088/1361-651X/ac03a6/meta

** HECC provided supercomputing resources and services in support of this work*

Papers (cont.)

- "**TOI-220 b: A Warm Sub-Neptune Discovered by TESS**," S. Hoyer, et al., Monthly Notices of the Royal Astronomical Society, published online May 22, 2021. *
https://academic.oup.com/mnras/advance-article-abstract/doi/10.1093/mnras/stab1427/6280968
- "**Fe XII and Fe XIII Line Widths in the Polar Off-limb Solar Corona up to 1.5 $R_{\odot}$**," Y. Zhu, J. Szente, E. Landi, The Astrophysical Journal, vol. 913, no. 1, May 26, 2021. *
https://iopscience.iop.org/article/10.3847/1538-4357/abf1e3/meta
- "**TIC 45410642: A Compact, Coplanar, Quadruple-lined Quadruple Star System Consisting of Two Eclipsing Binaries**," V. Kostov, et al., arXiv:2105.12586 [astro-ph.SR], May 26, 2021. *
https://arxiv.org/abs/2105.12586
- "**Resolving Pitching Airfoil Transonic Aerodynamics by Computational Fluid Dynamics Data Modeling**," U. Kaul, Journal of Fluids Engineering, vol. 143, issue 9, May 27, 2021. *
https://asmedigitalcollection.asme.org/fluidsengineering/article/143/9/091501/1106713/Resolving-Pitching-Airfoil-Transonic-Aerodynamics
- "**Impacts of Sea-Level Rise on Hypoxia and Phytoplankton Production in Chesapeake Bay: Model Prediction and Assessment**," X. Cai, J. Shen, Y. Zhang, Q. Qin, Z. Wang, H. Wong, Journal of the American Water Resources Association, published online May 27, 2021. *
https://onlinelibrary.wiley.com/doi/abs/10.1111/1752-1688.12921

** HECC provided supercomputing resources and services in support of this work*

Papers (cont.)

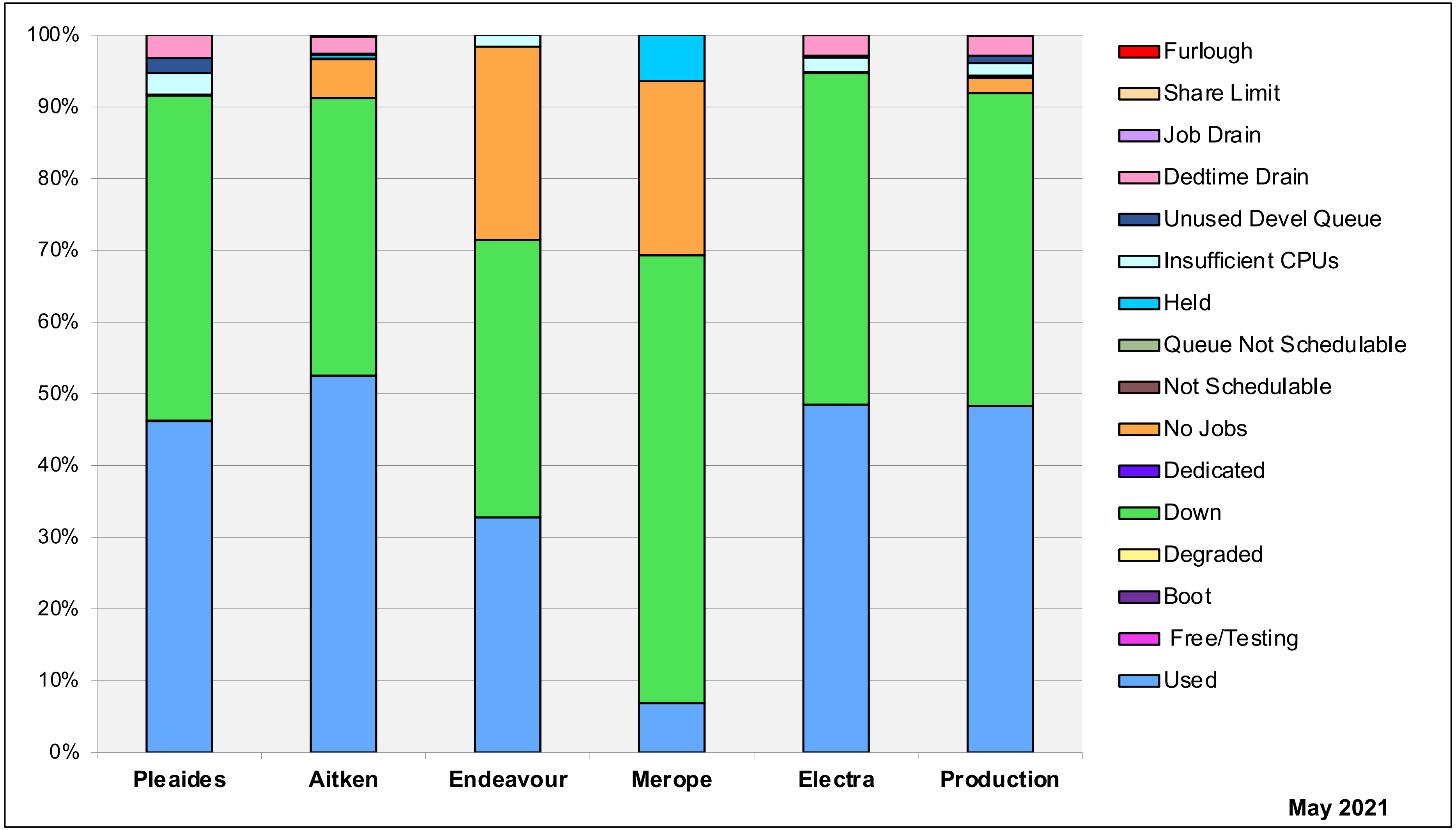
- “**Magnetosphere Reconnection and Indents Induced by Foreshock Turbulence**,” L.-J. Chen, J. Ng, Y, Omelchenko, S. Wang, Geophysical Research Letters, published online May 31, 2021. *
https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021GL093029?af=R

** HECC provided supercomputing resources and services in support of this work*

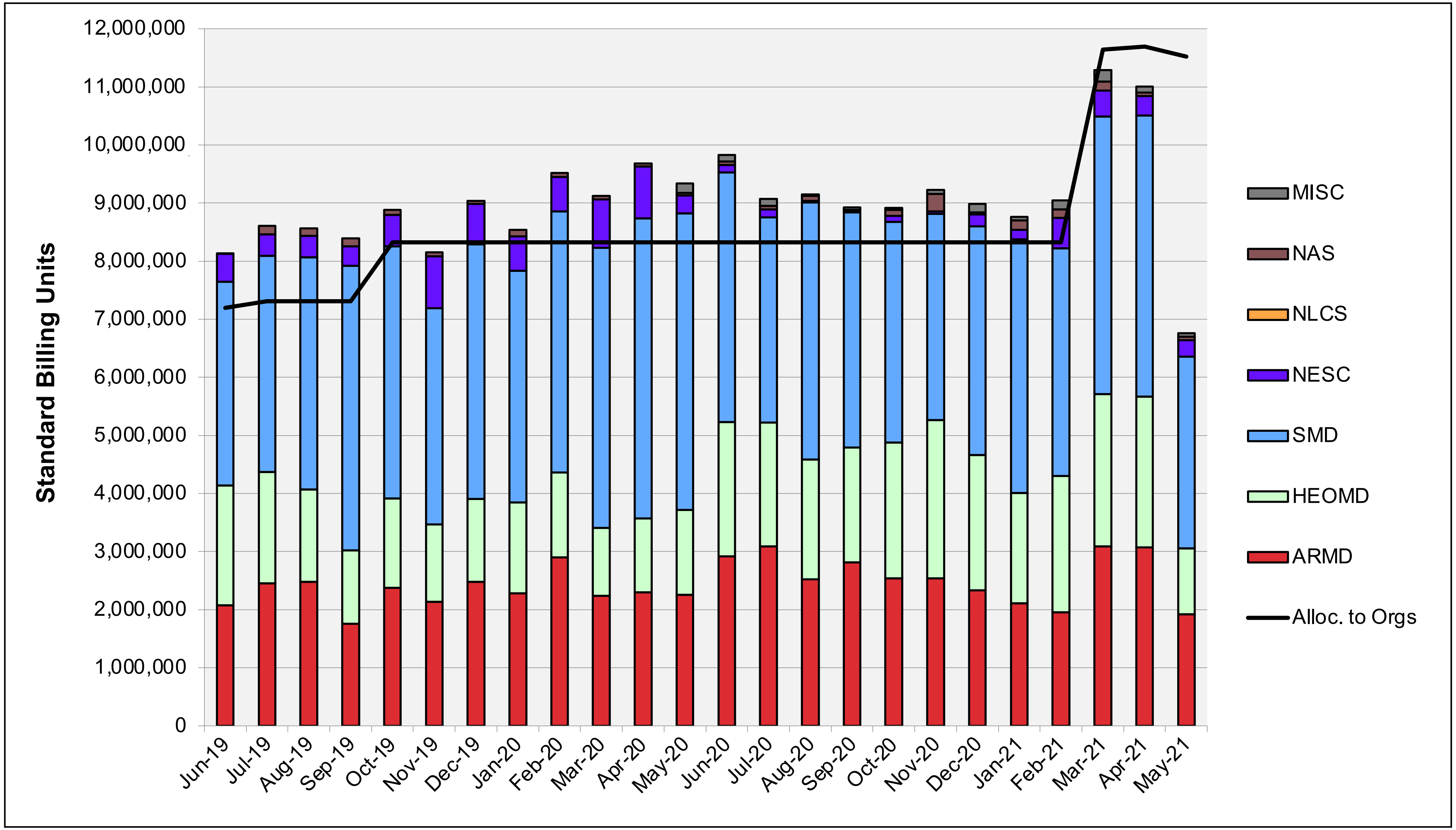
News and Events: Social Media

- **Coverage of NAS Stories**
  - Asteroid Threat Assessment Project (Ames Feature):
    - NAS: Twitter 2 retweets, 7 favorites
    - NASA Supercomputing: Facebook 115 users reached, 10 engagements, 5 likes.
  - Facebook Live with JPL Researcher Dimitris Menemenlis on Ocean Modeling:
    - NASA Supercomputing: Facebook 88 users reached, 8 engagements, 5 likes.

HECC Utilization



HECC Utilization Normalized to 30-Day Month



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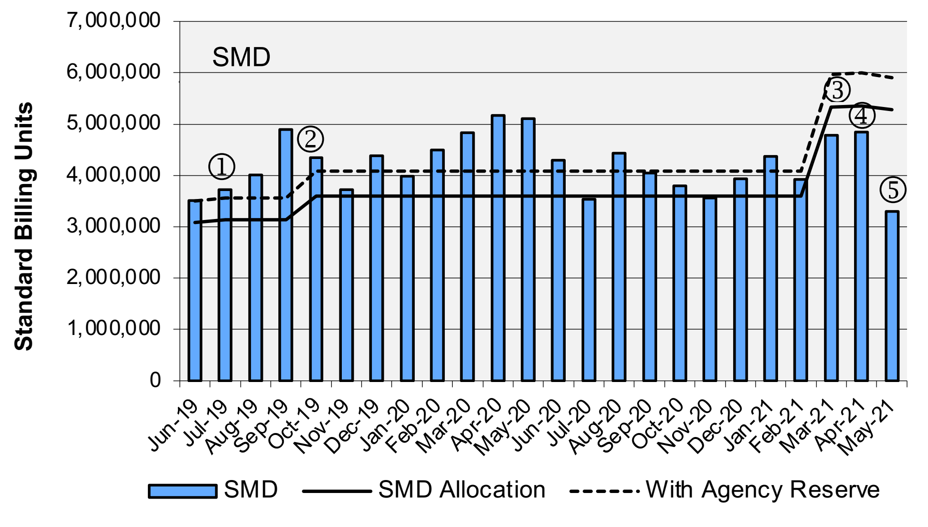
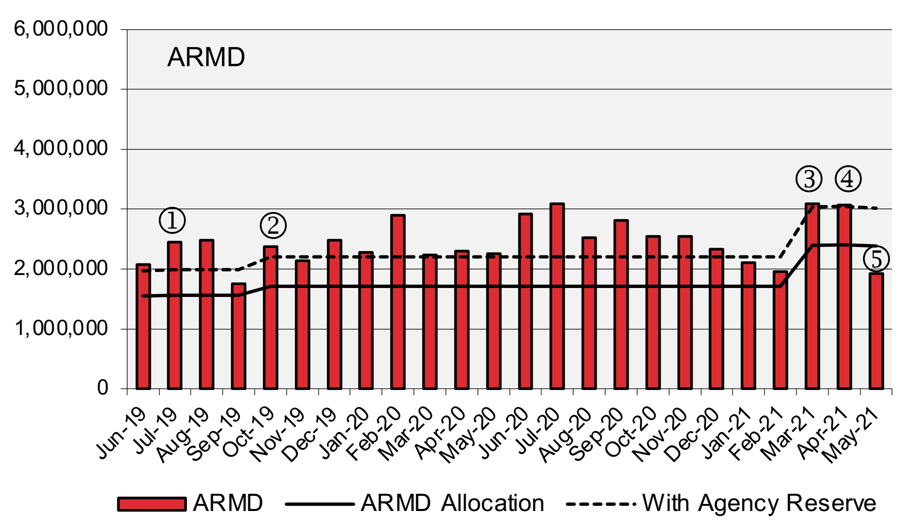
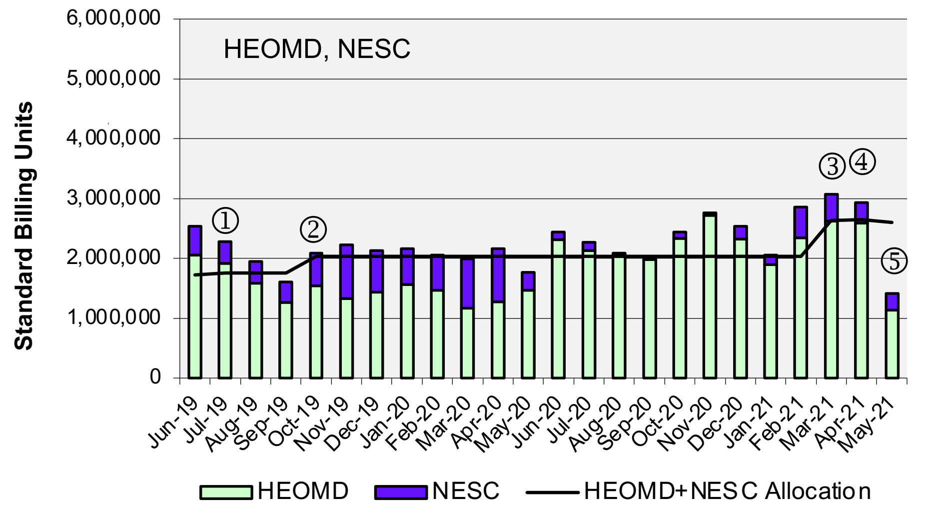






① Skylake Tesla GPU V100 Nodes installed

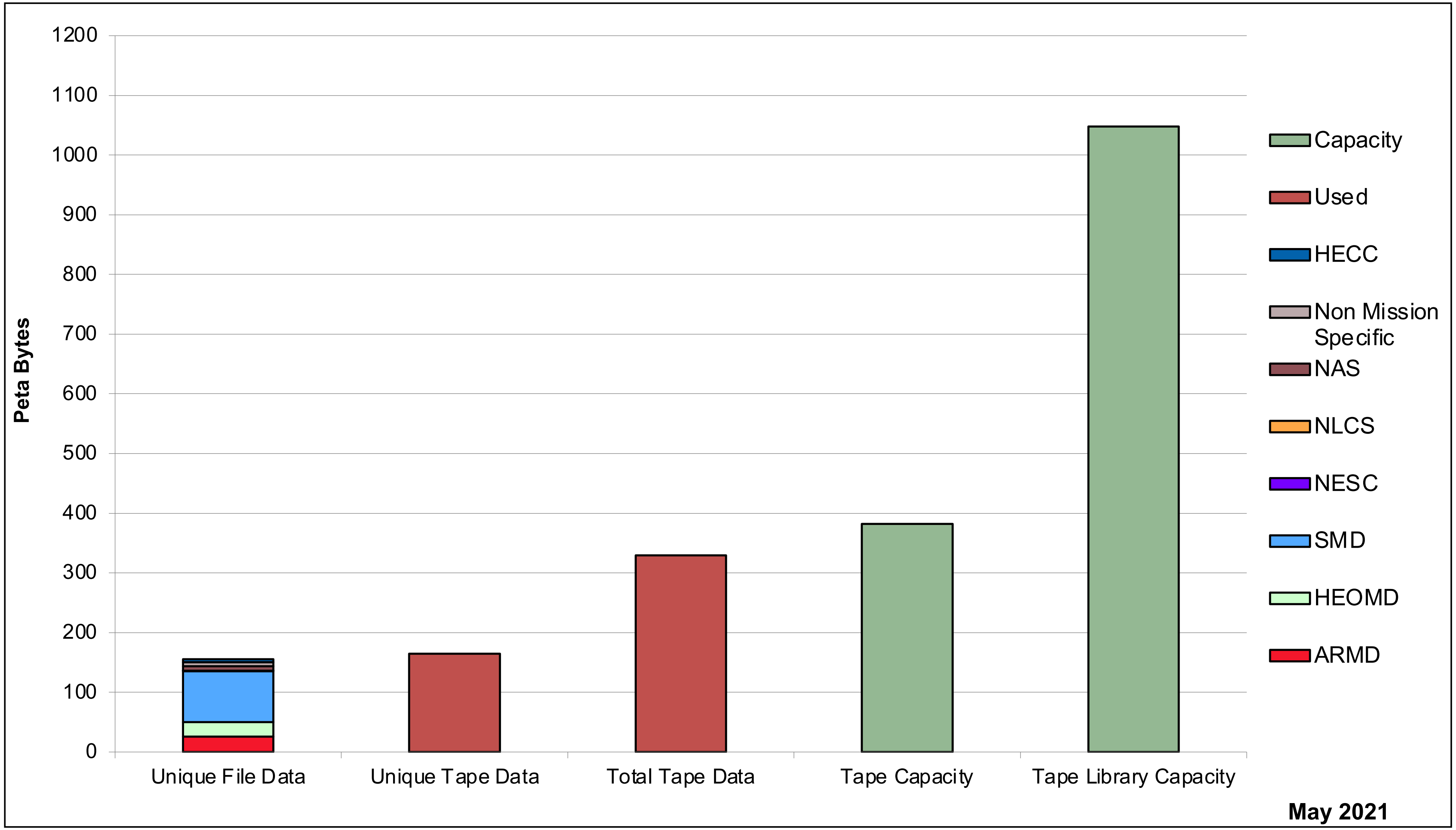
② 4 Cascade Lake E cells introduced into Aitken

③ 8 Rome Apollo racks introduced into Aitken

④ Endeavour replaced with new hardware

⑤ Merope Retired

Tape Archive Status



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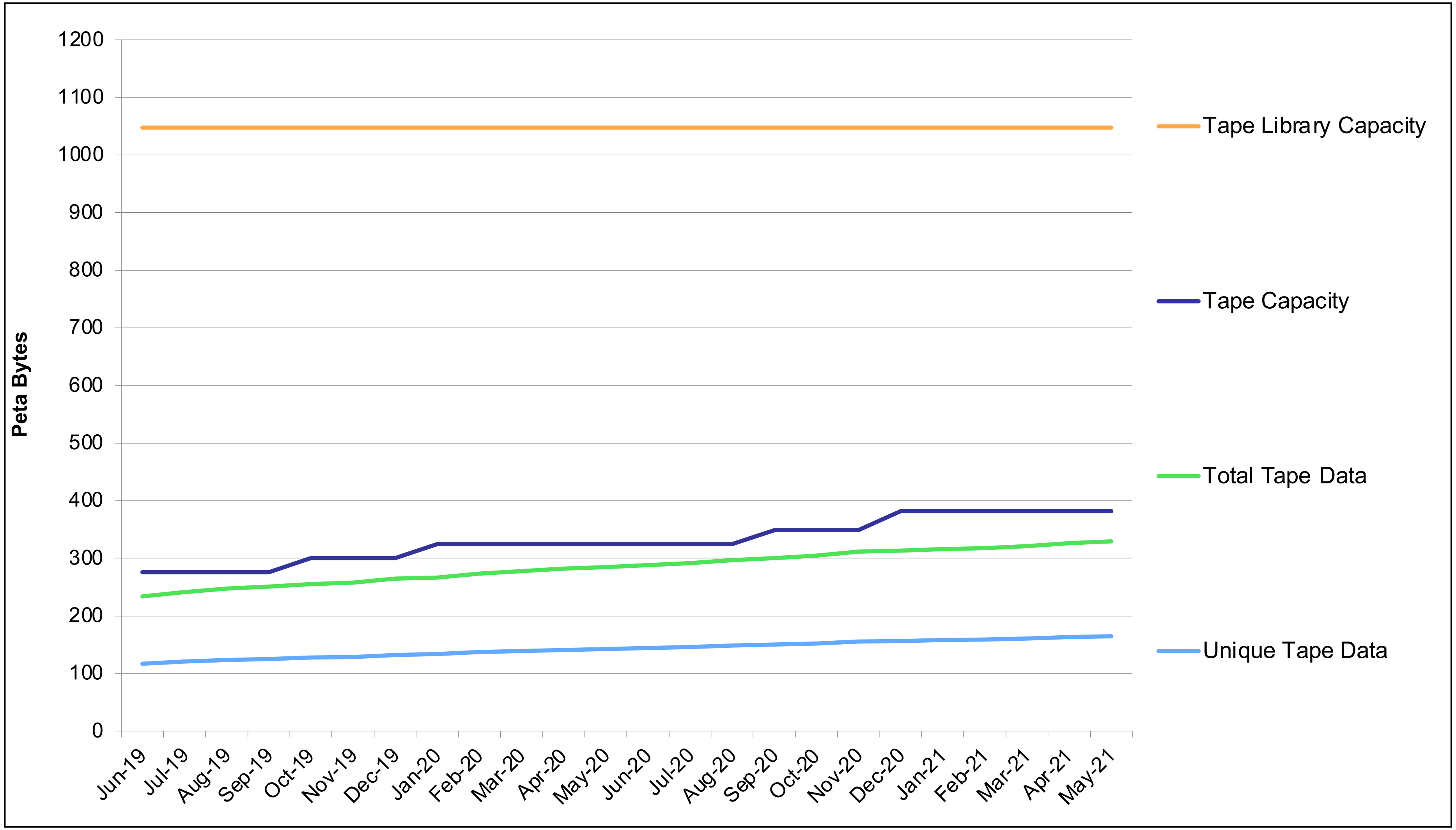
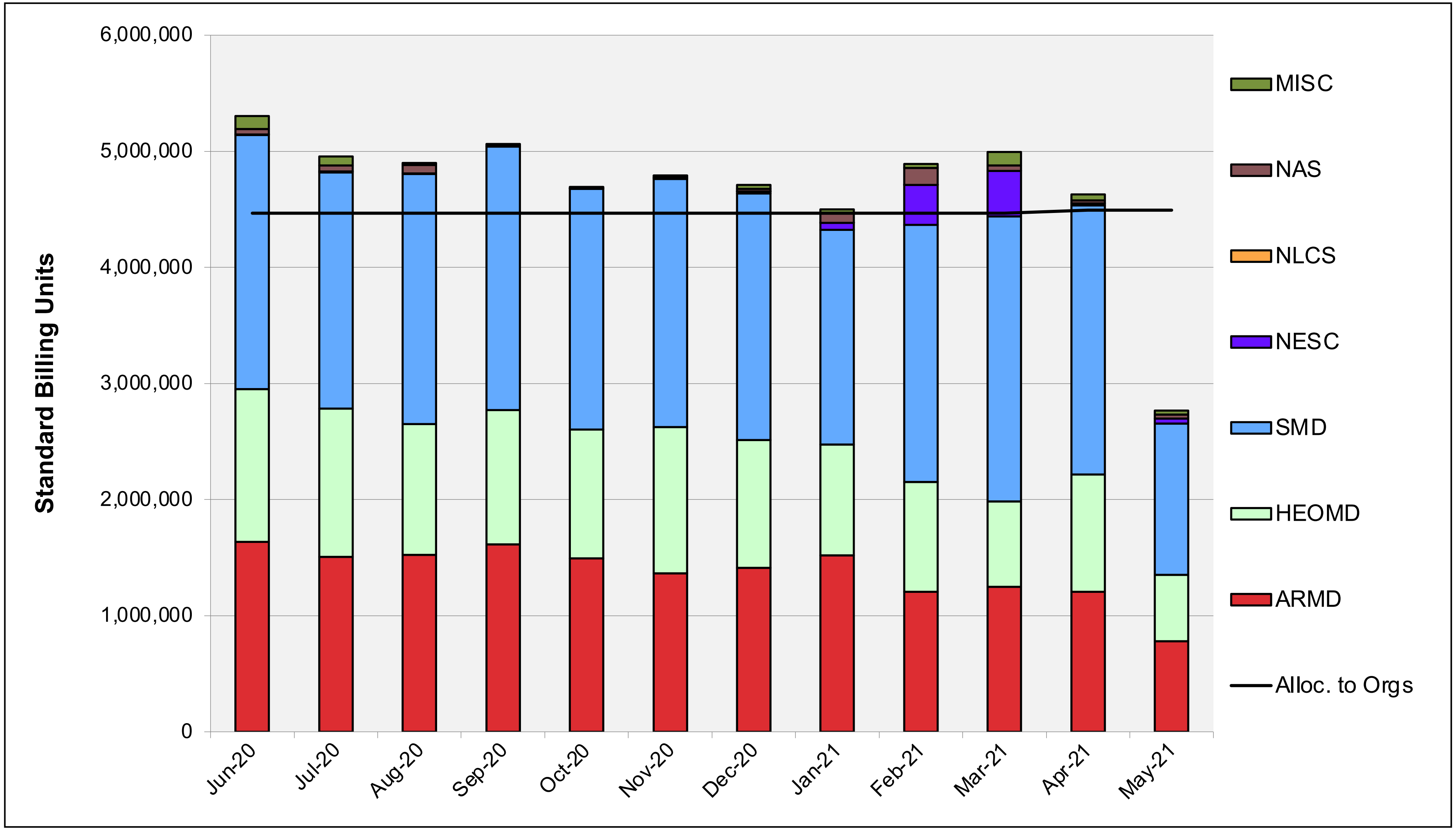
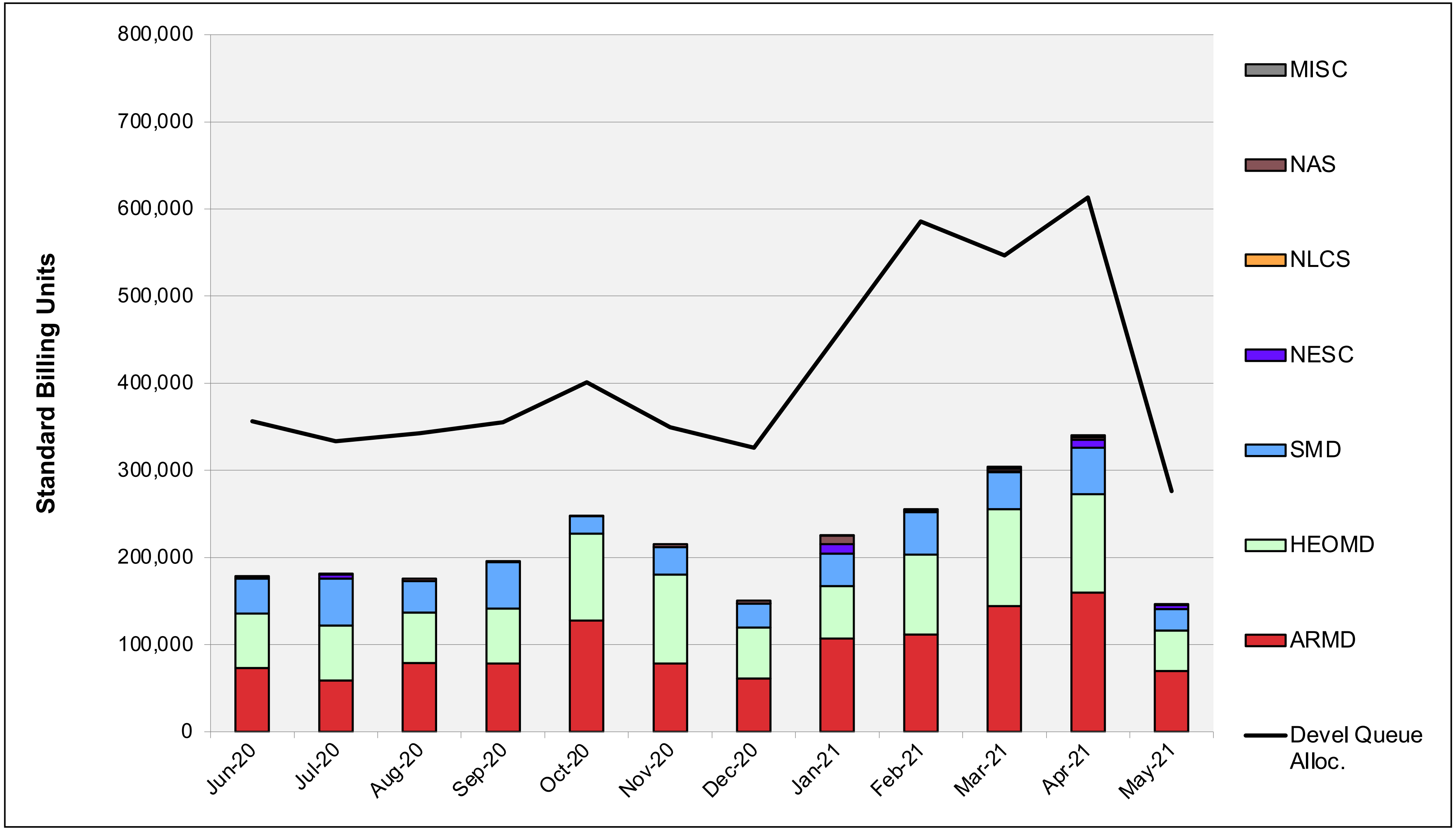


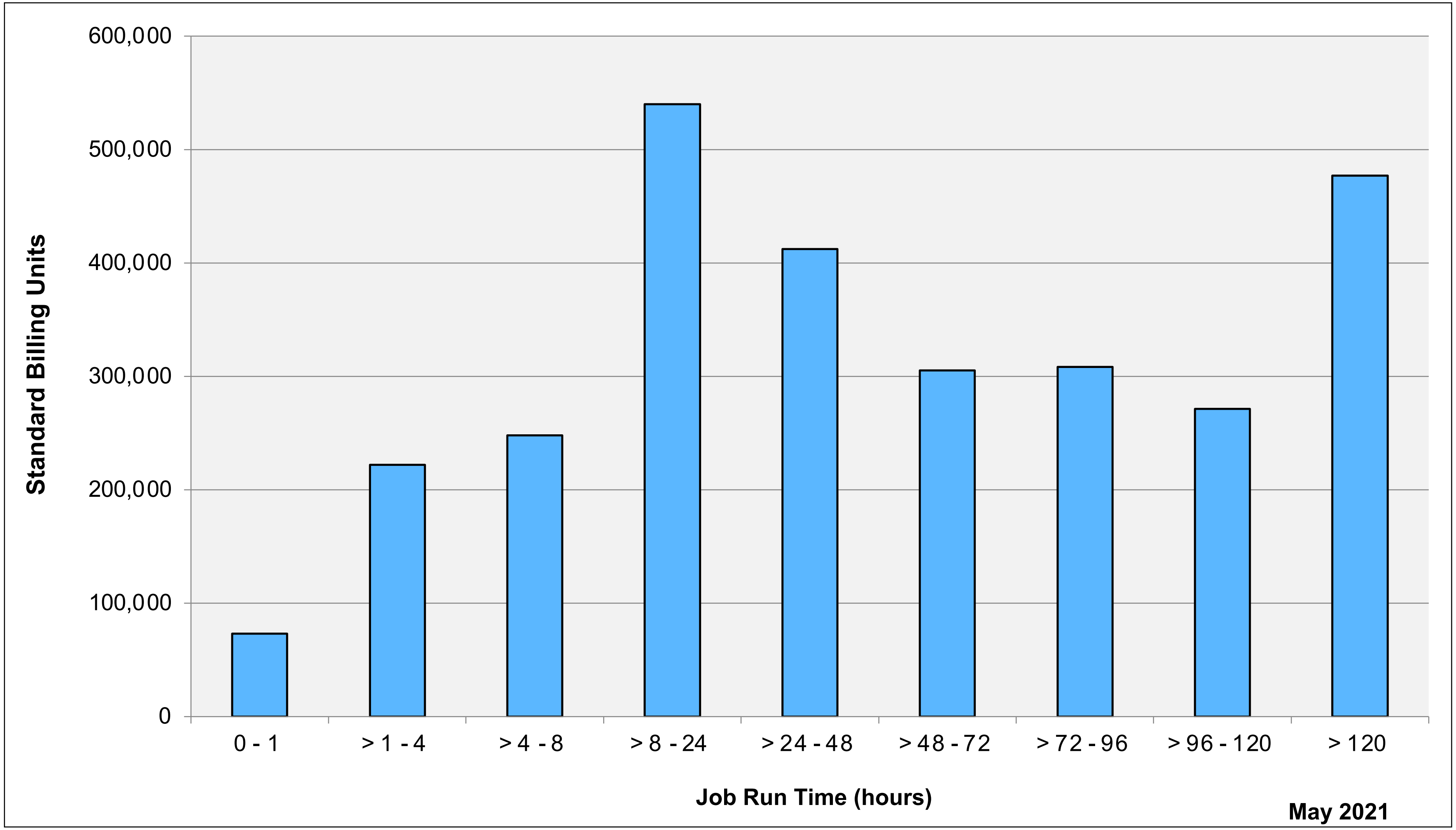
Pleiades: SBUs Reported, Normalized to 30-Day Month



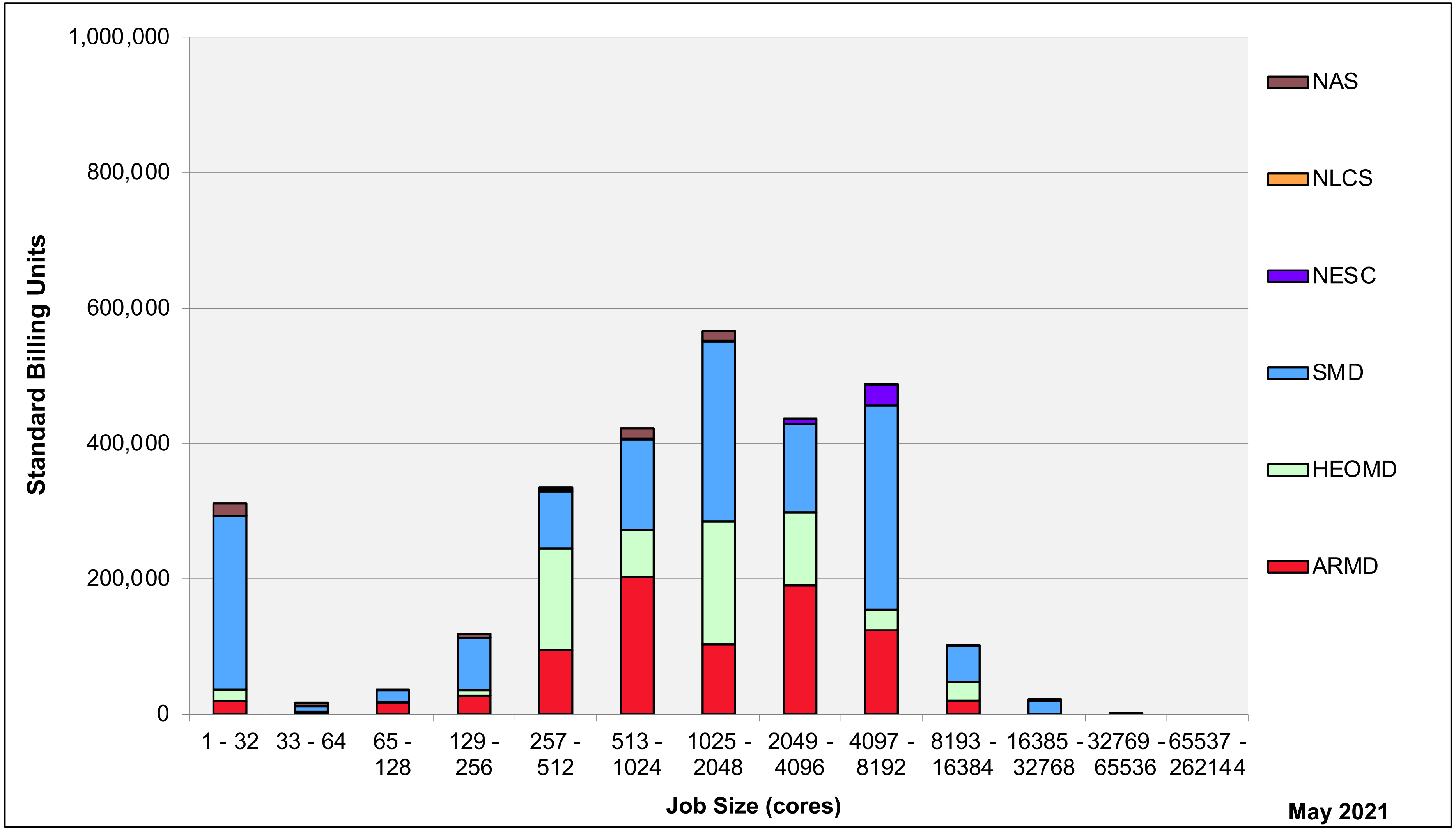
Pleiades: Devel Queue Utilization



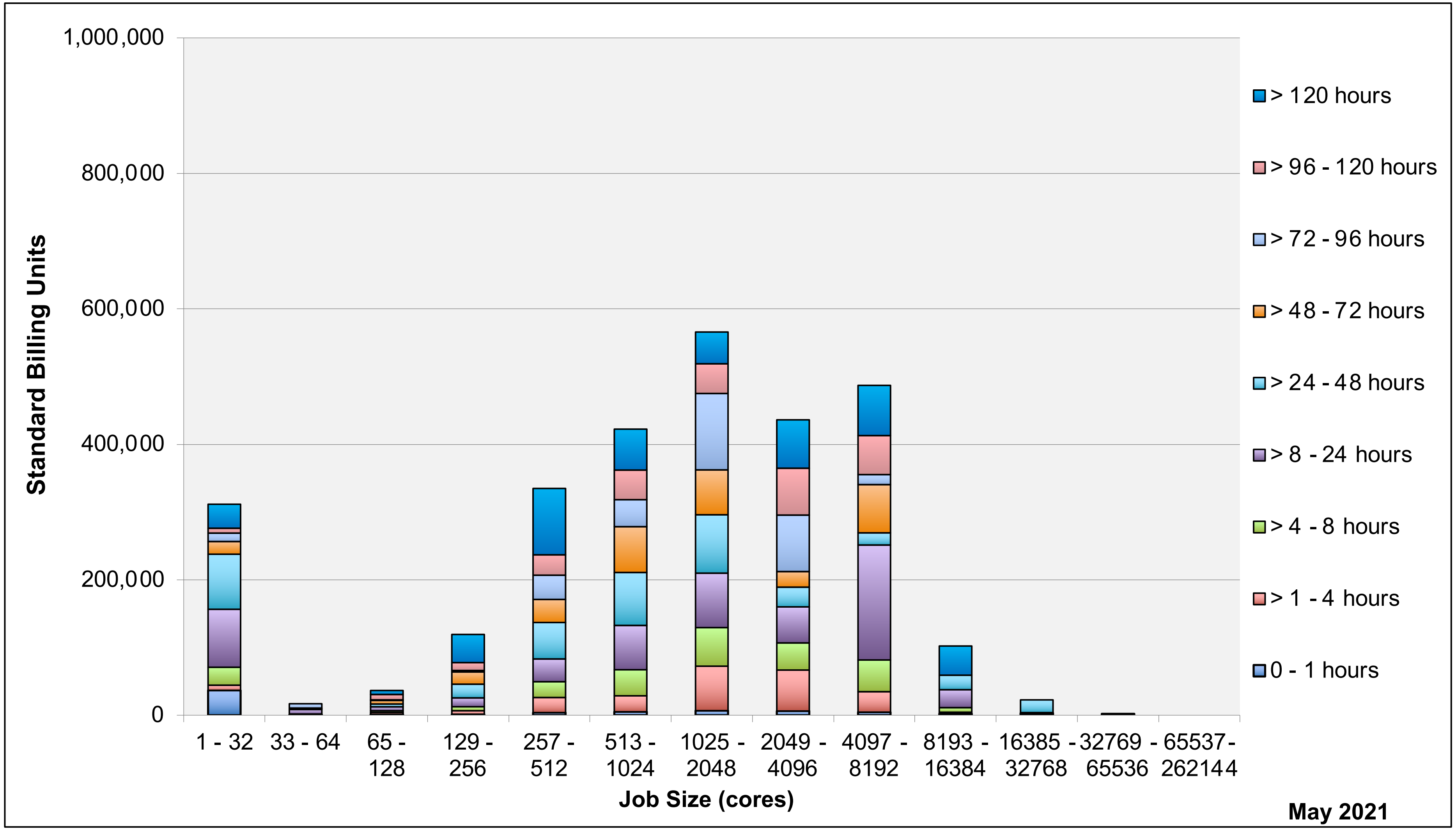
Pleiades: Monthly Utilization by Job Length



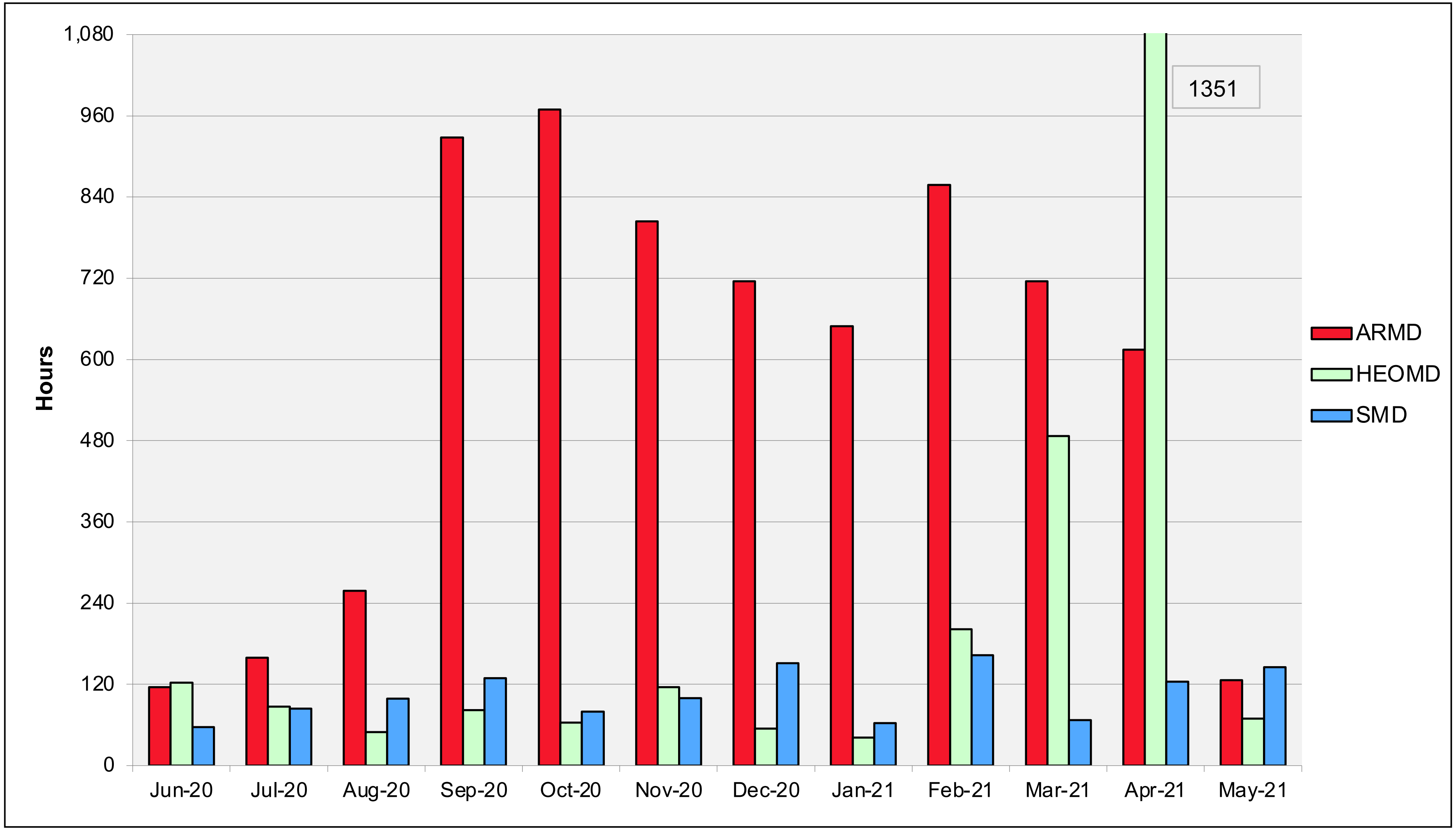
Pleiades: Monthly Utilization by Job Size



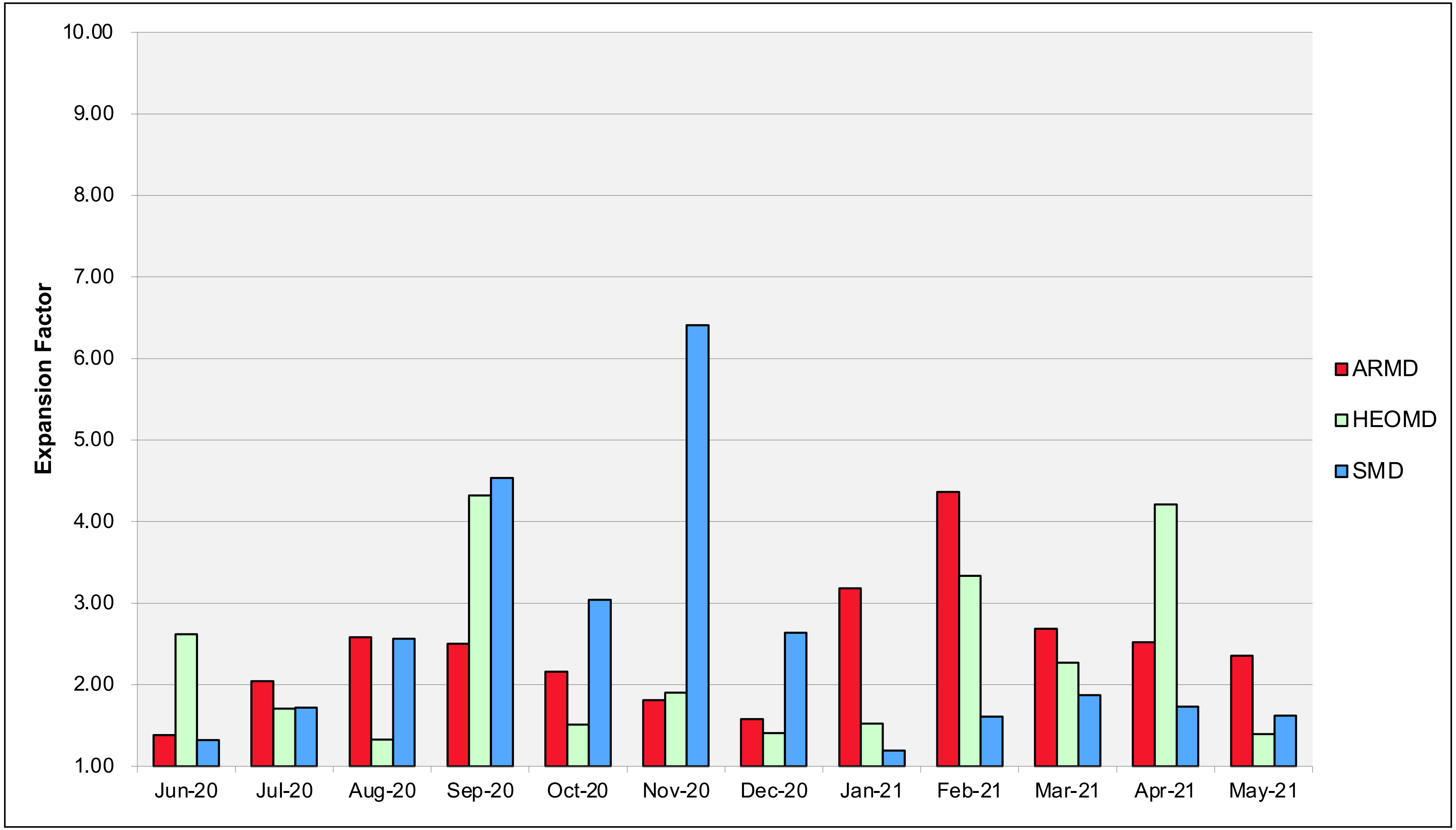
Pleiades: Monthly Utilization by Size and Length



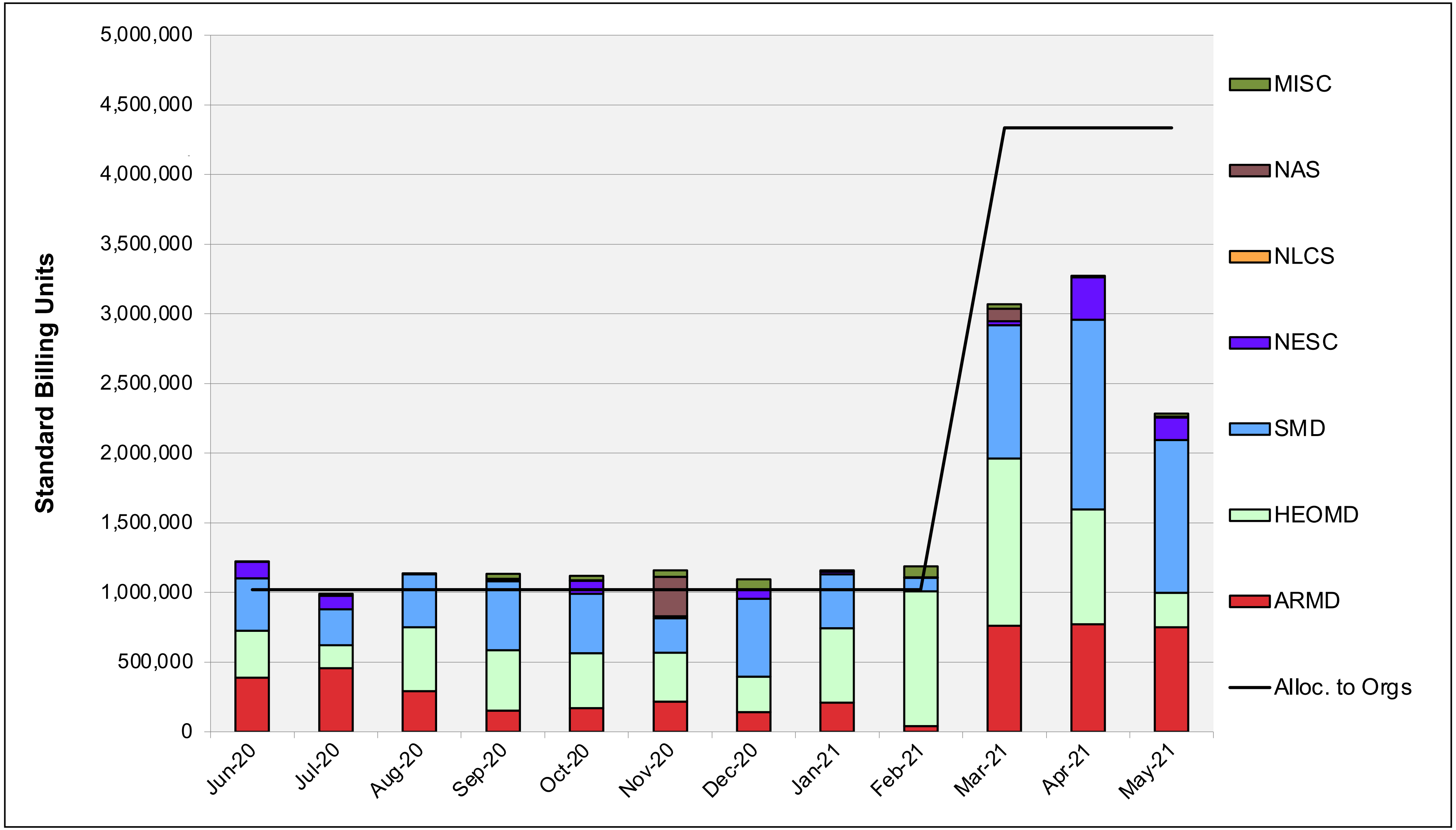
Pleiades: Average Time to Clear All Jobs



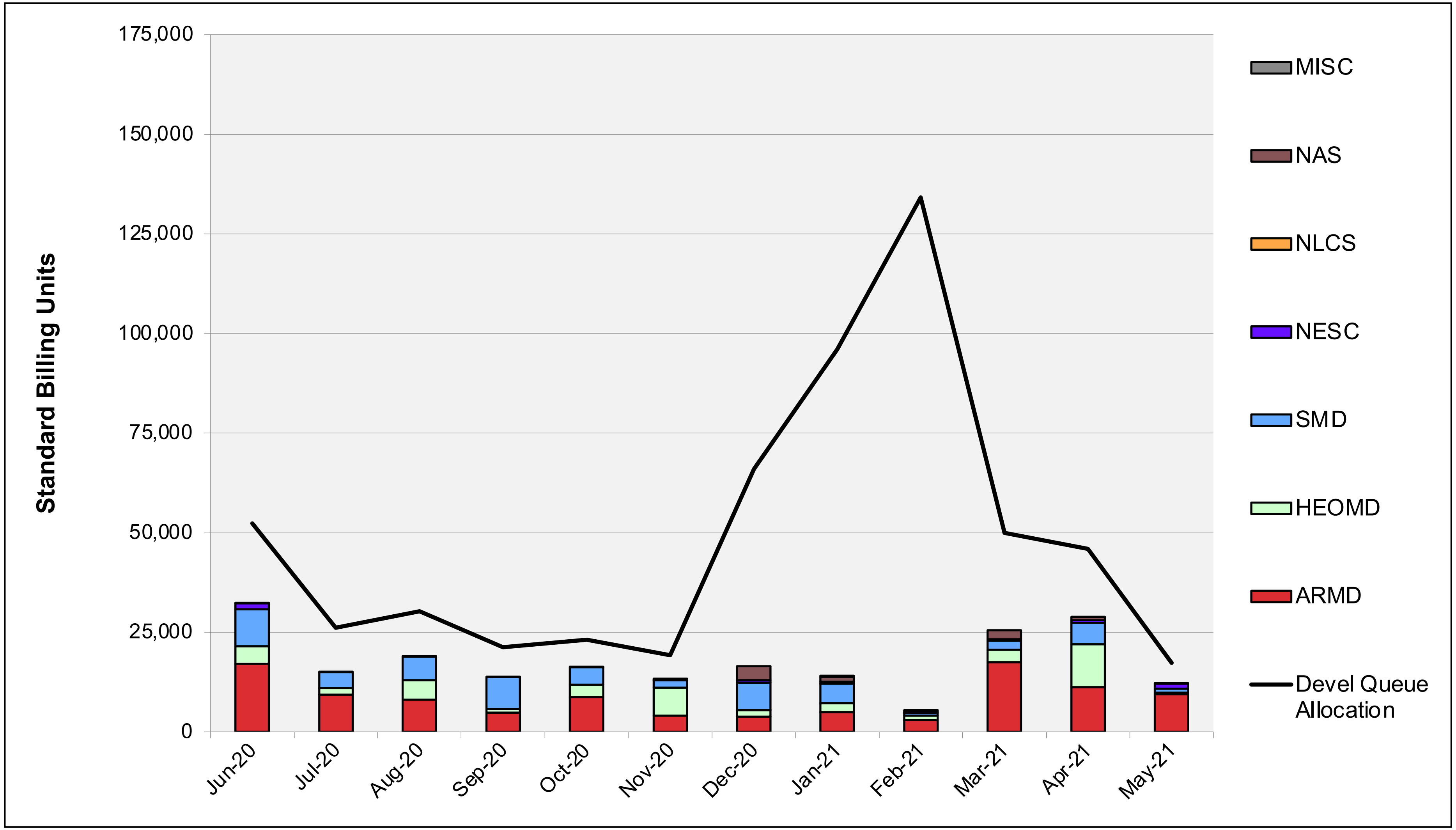
Pleiades: Average Expansion Factor



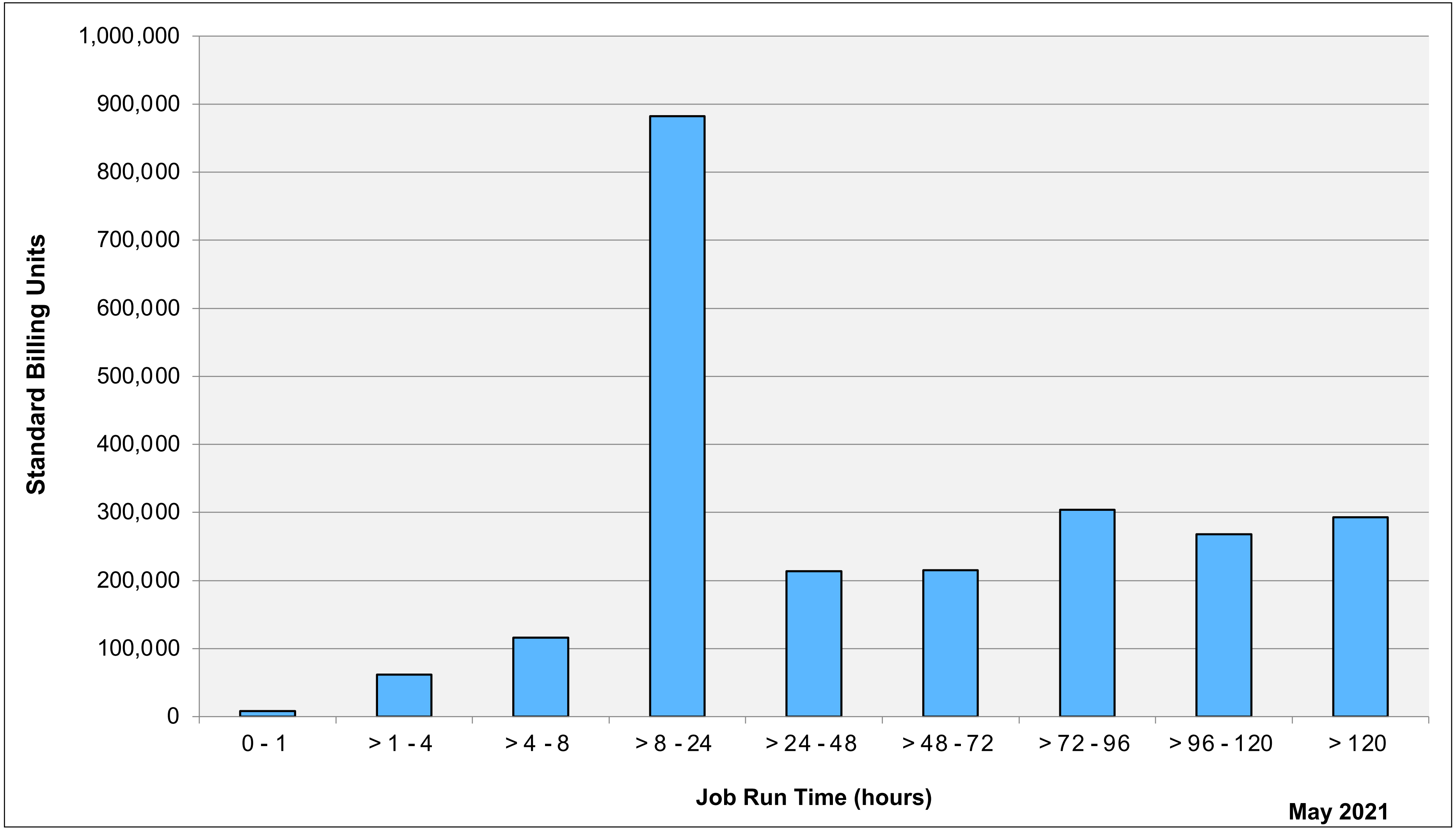
Aitken: SBUs Reported, Normalized to 30-Day Month



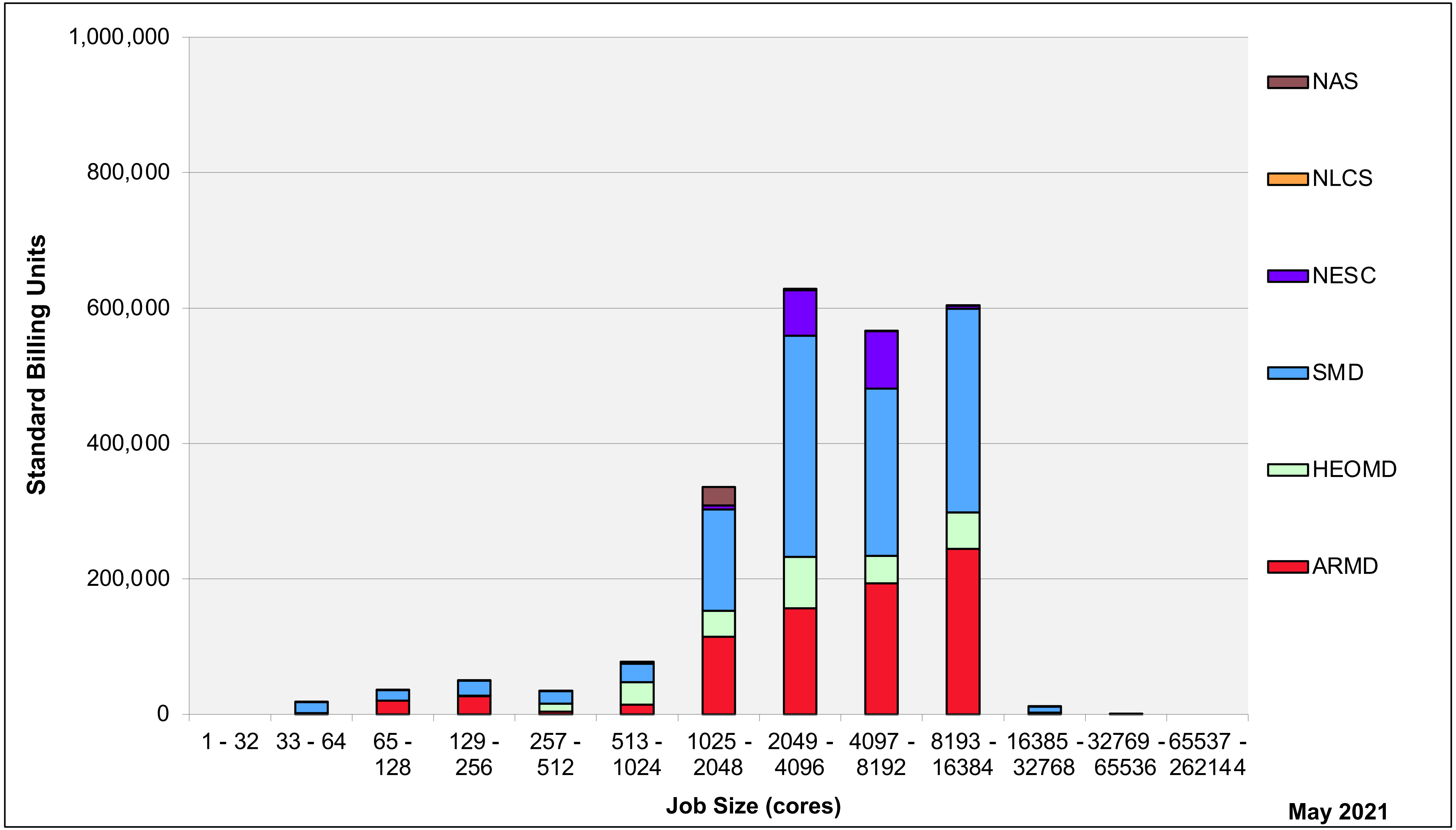
Aitken: Devel Queue Utilization



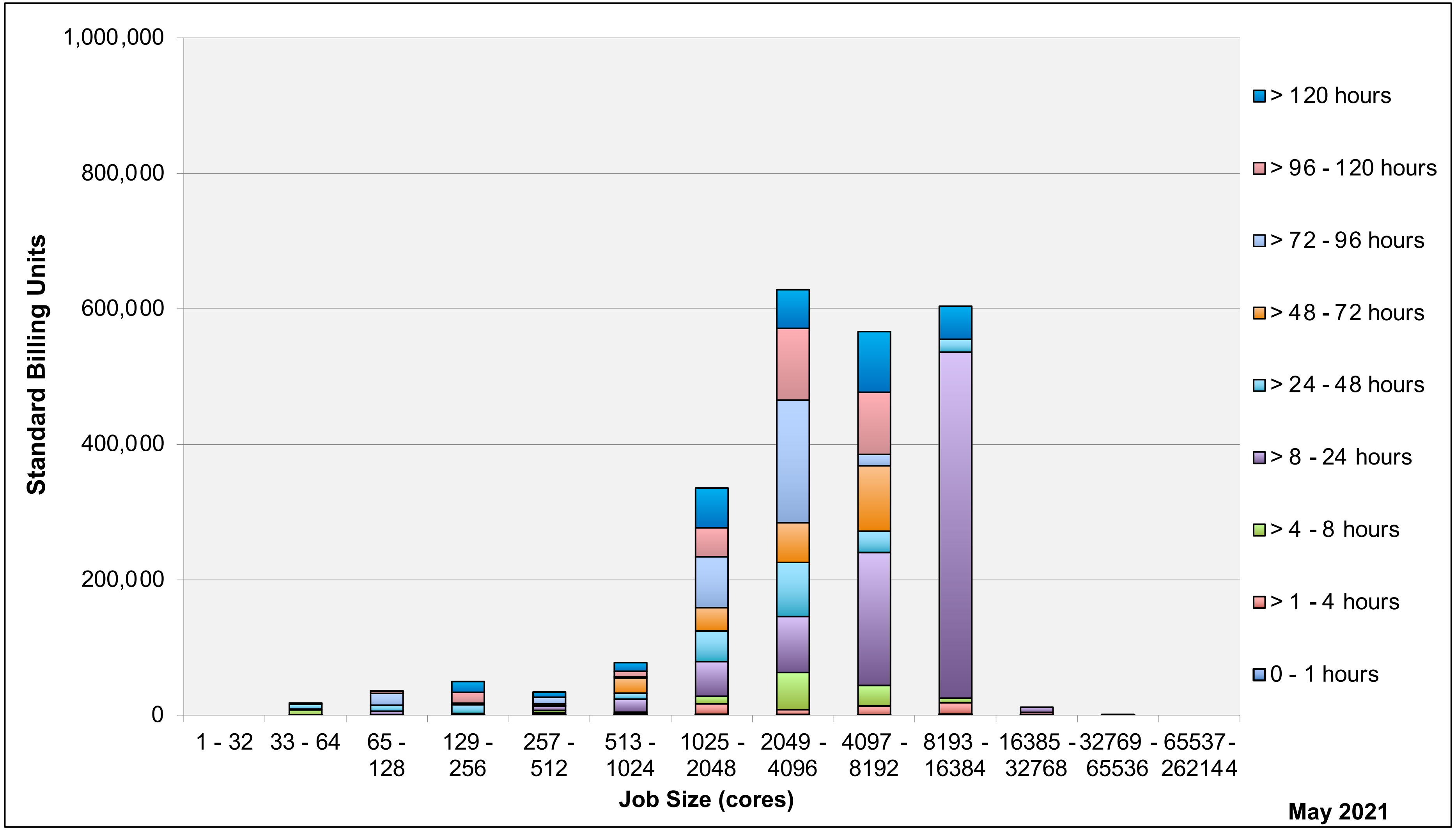
Aitken: Monthly Utilization by Job Length



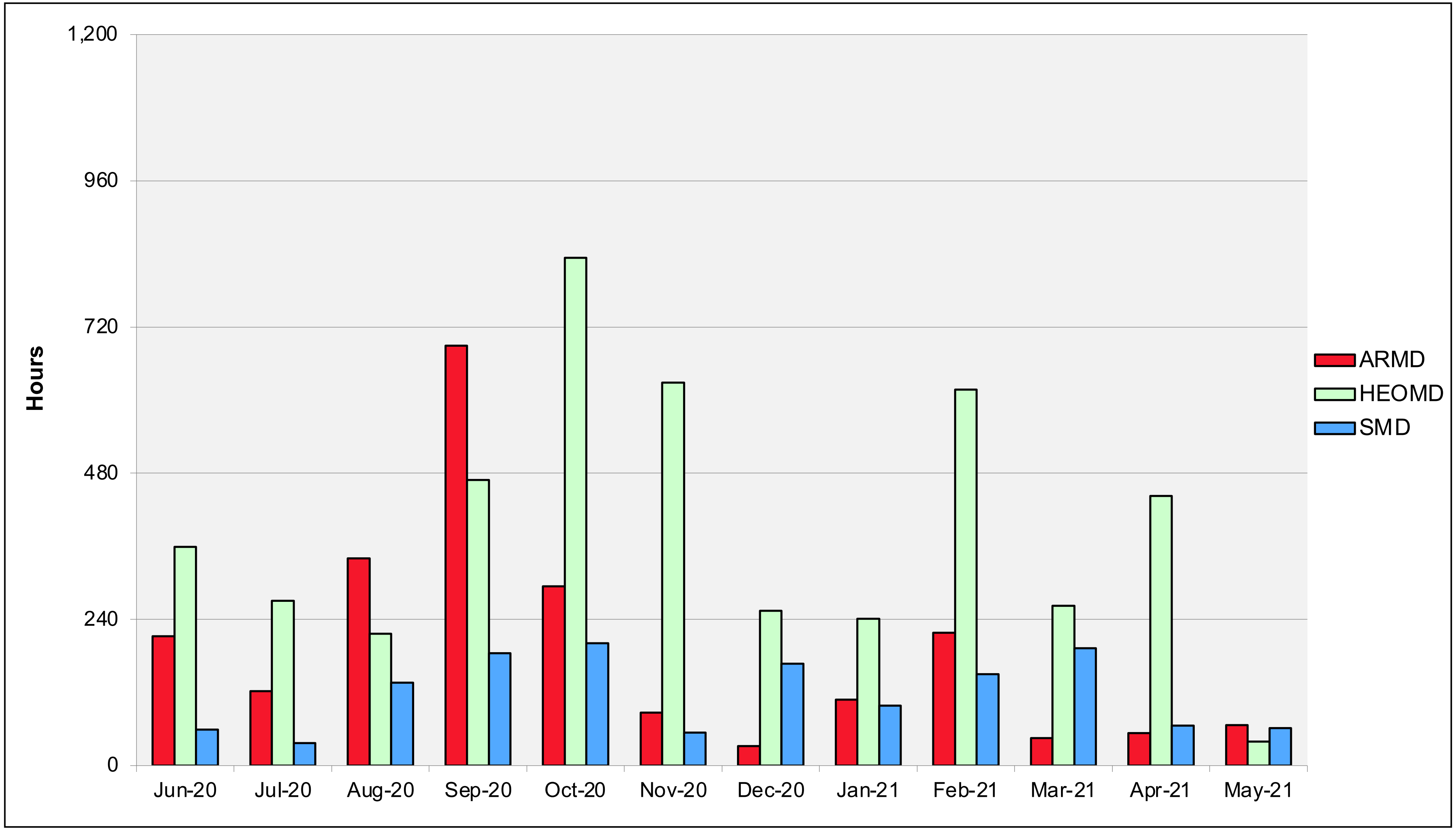
Aitken: Monthly Utilization by Job Size



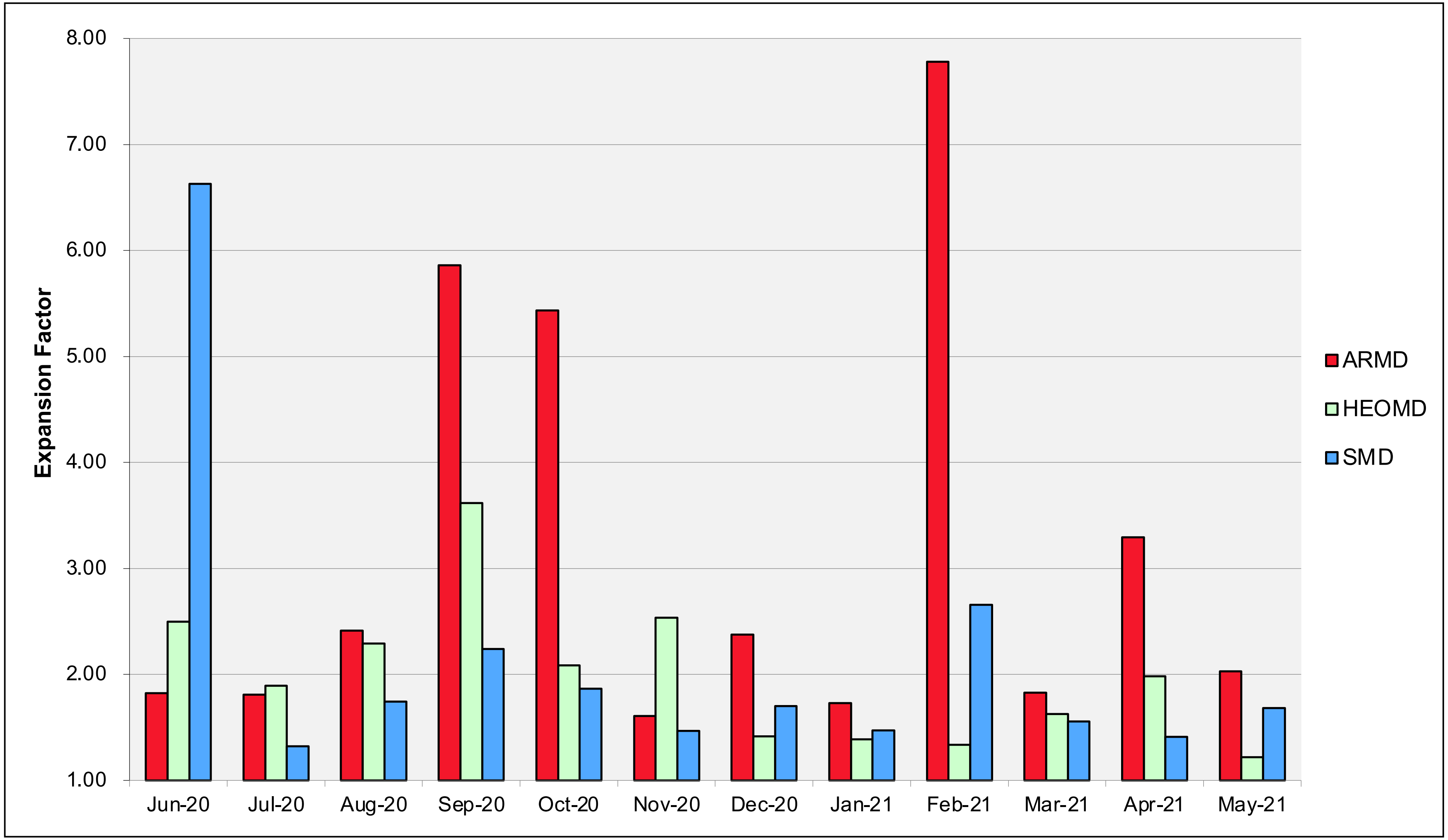
Aitken: Monthly Utilization by Size and Length



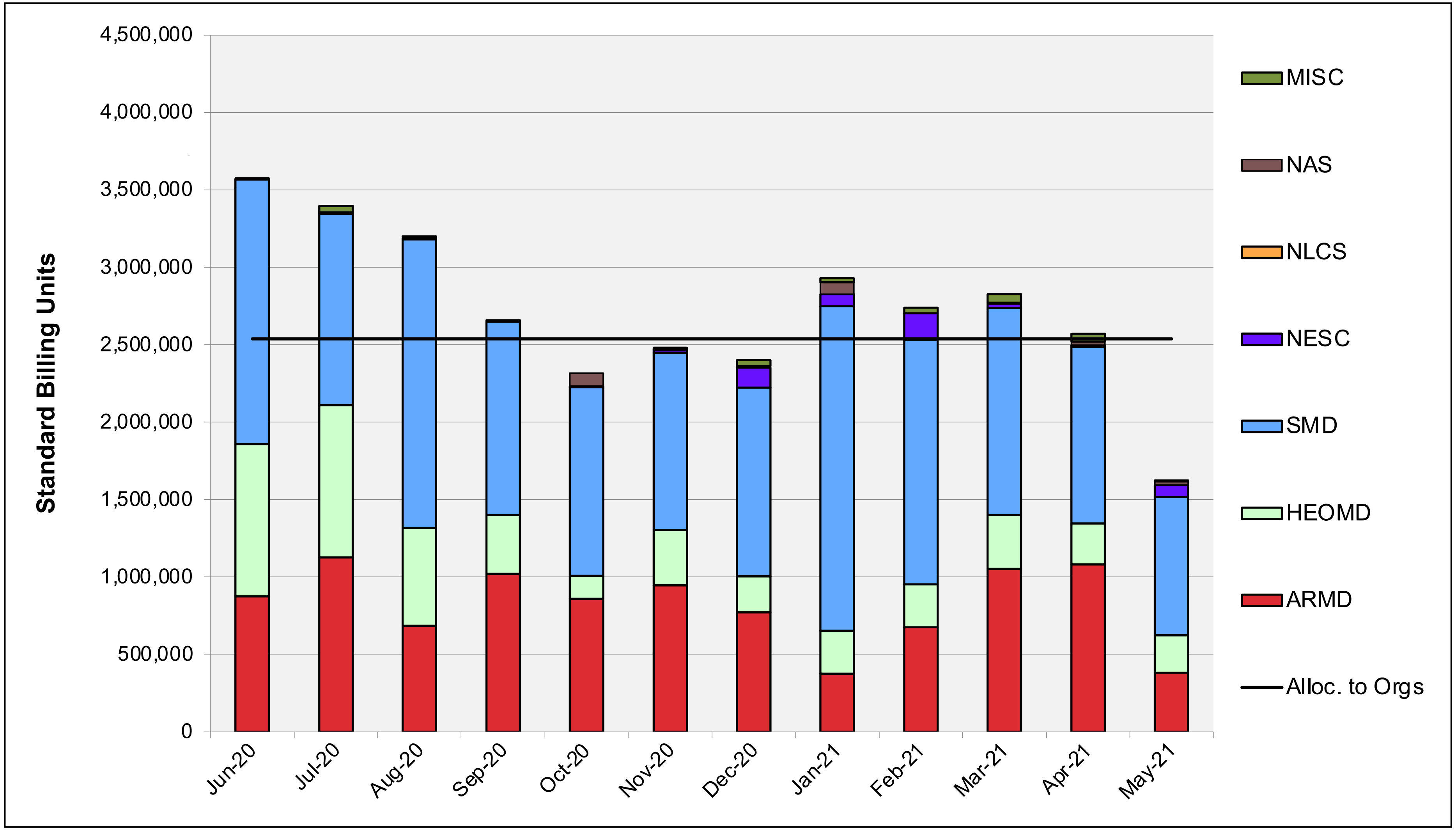
Aitken: Average Time to Clear All Jobs



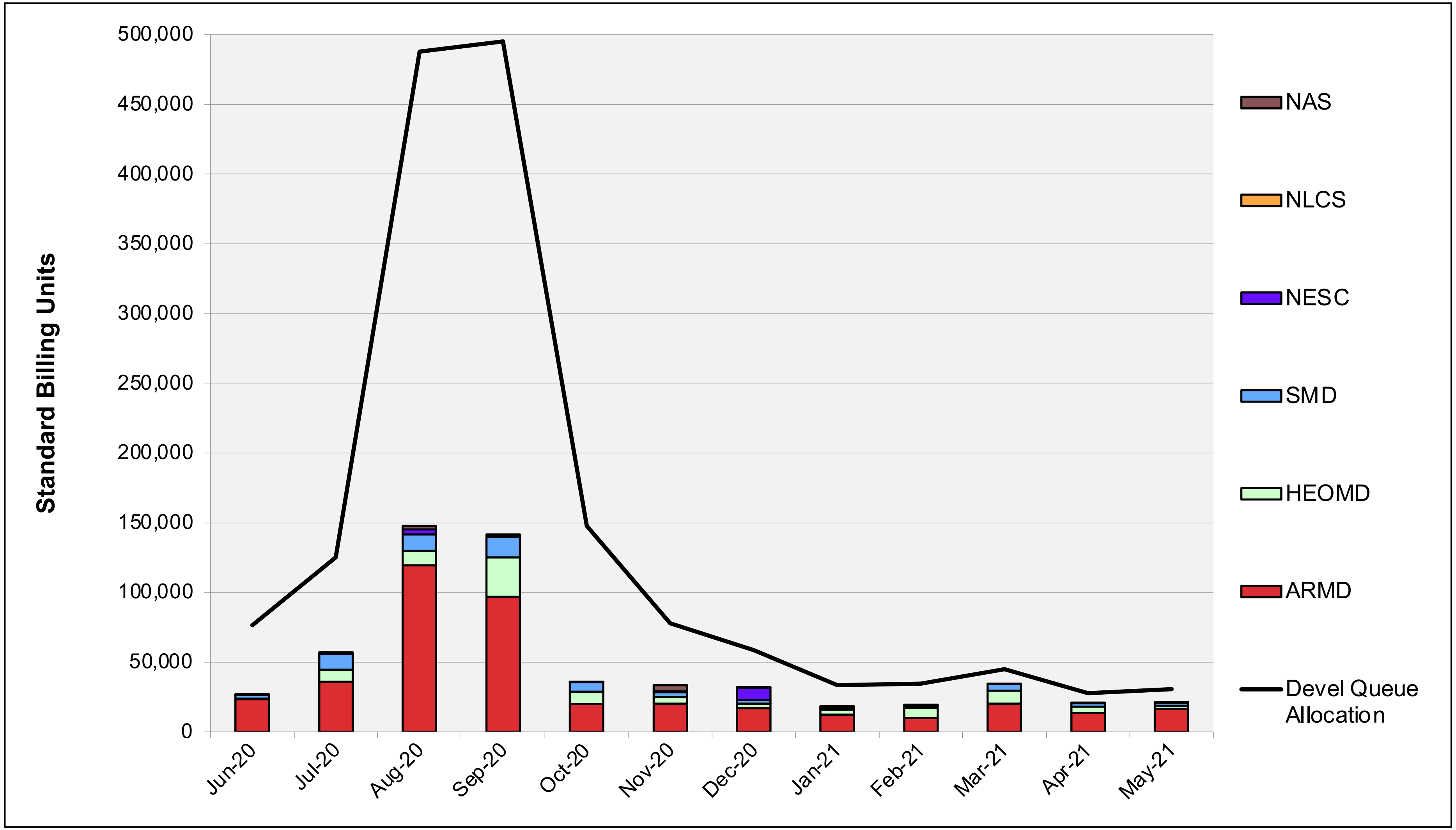
Aitken: Average Expansion Factor



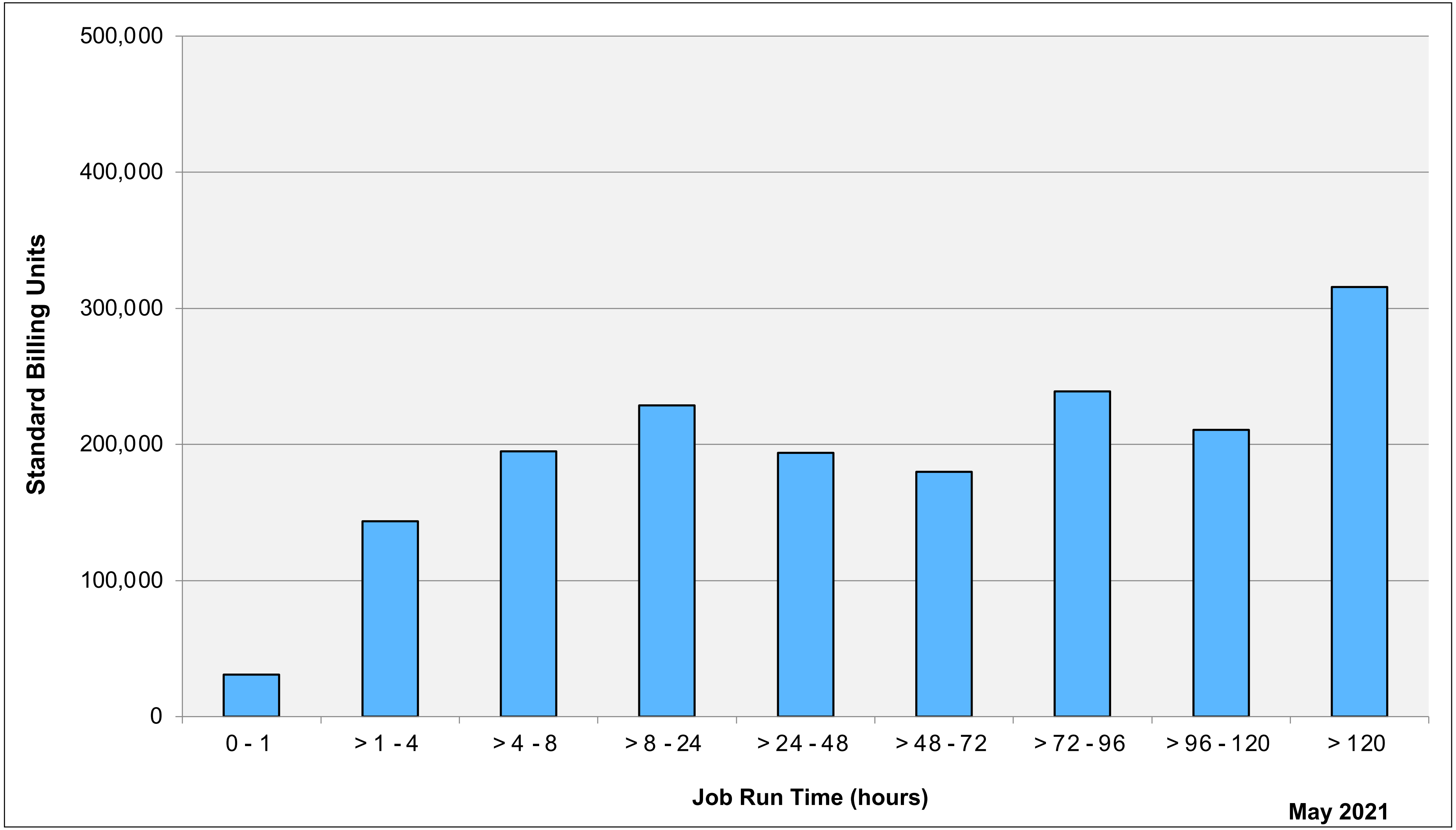
Electra: SBUs Reported, Normalized to 30-Day Month



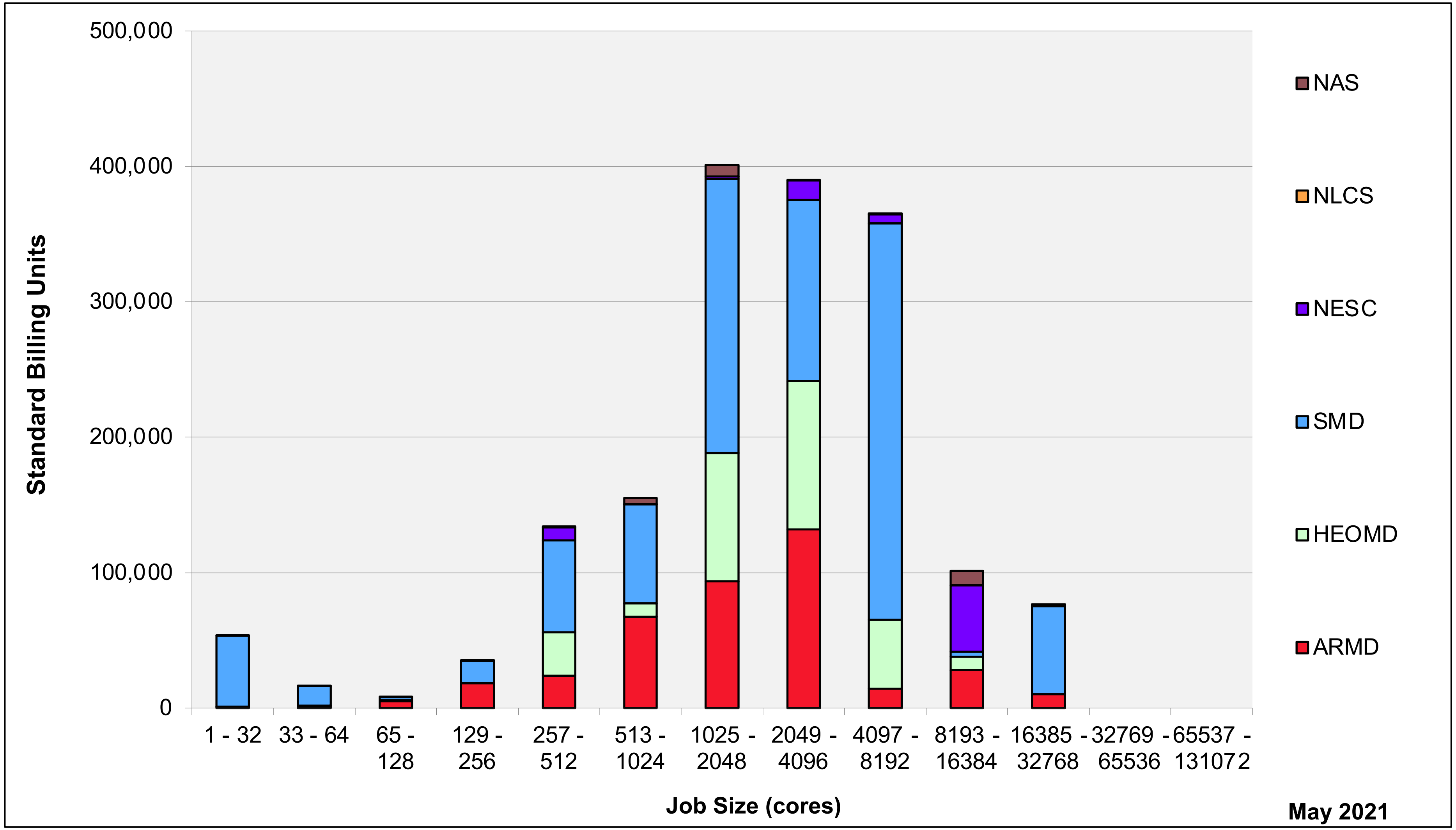
Electra: Devel Queue Utilization



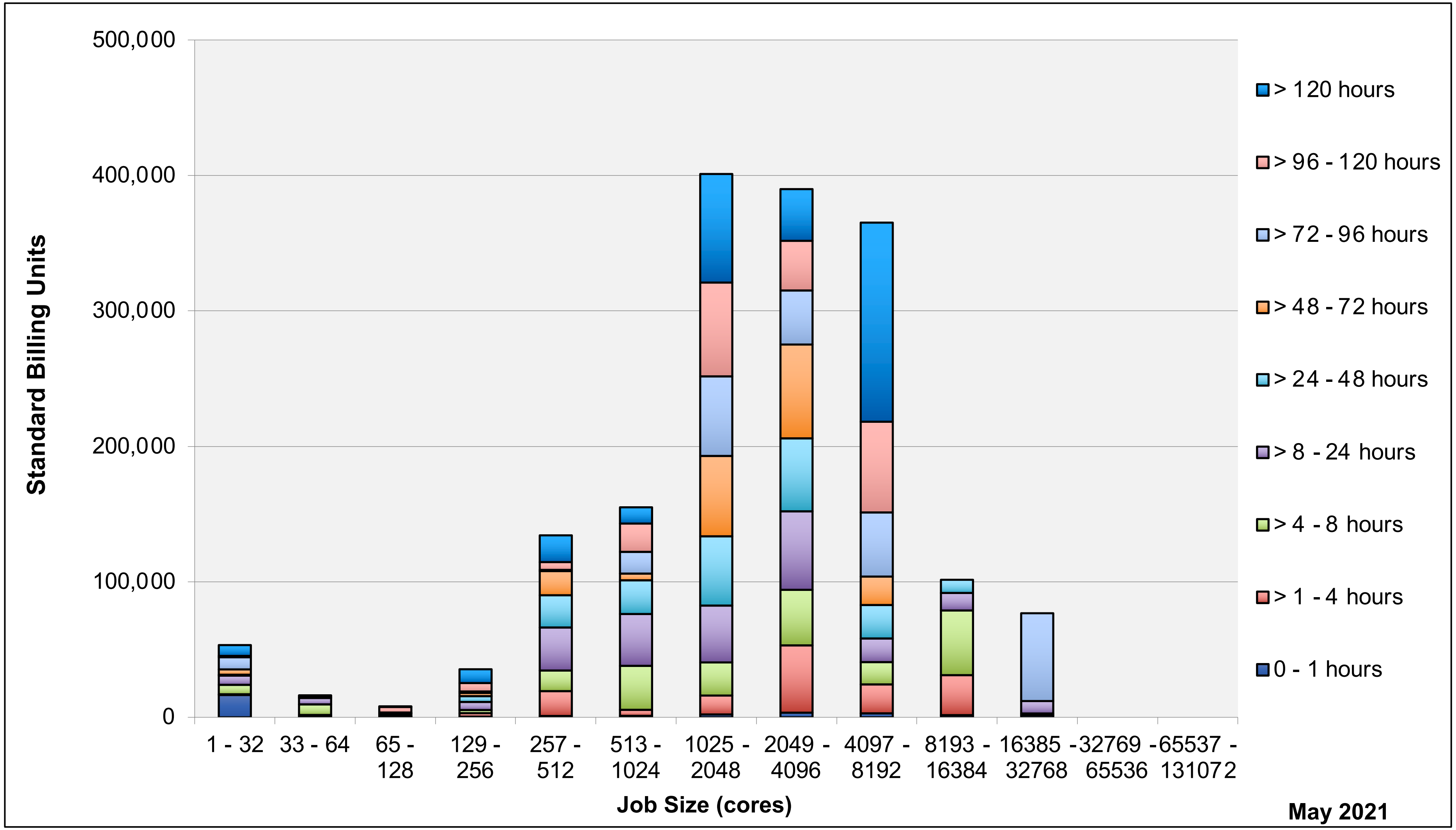
Electra: Monthly Utilization by Job Length



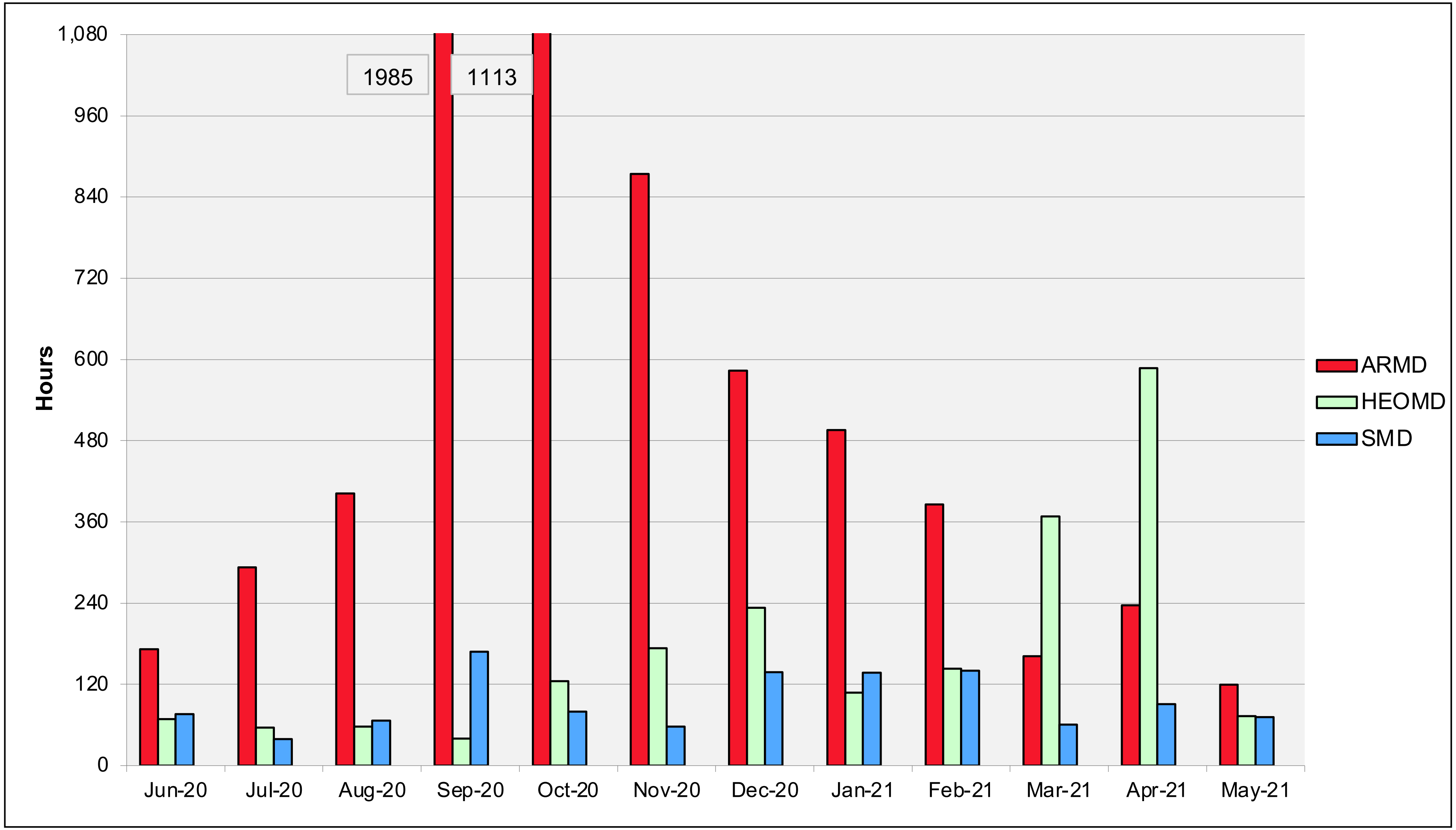
Electra: Monthly Utilization by Job Size



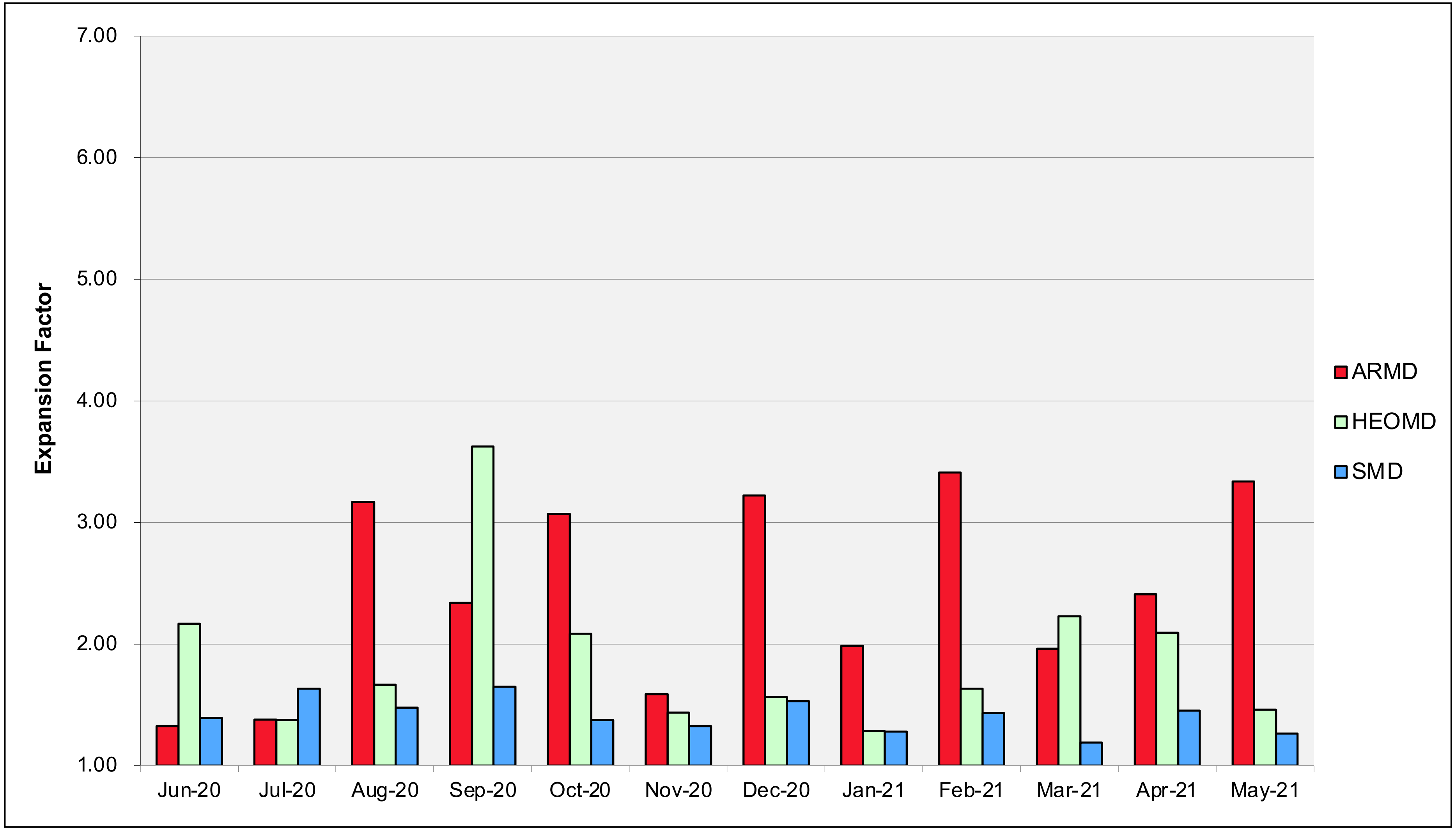
Electra: Monthly Utilization by Size and Length



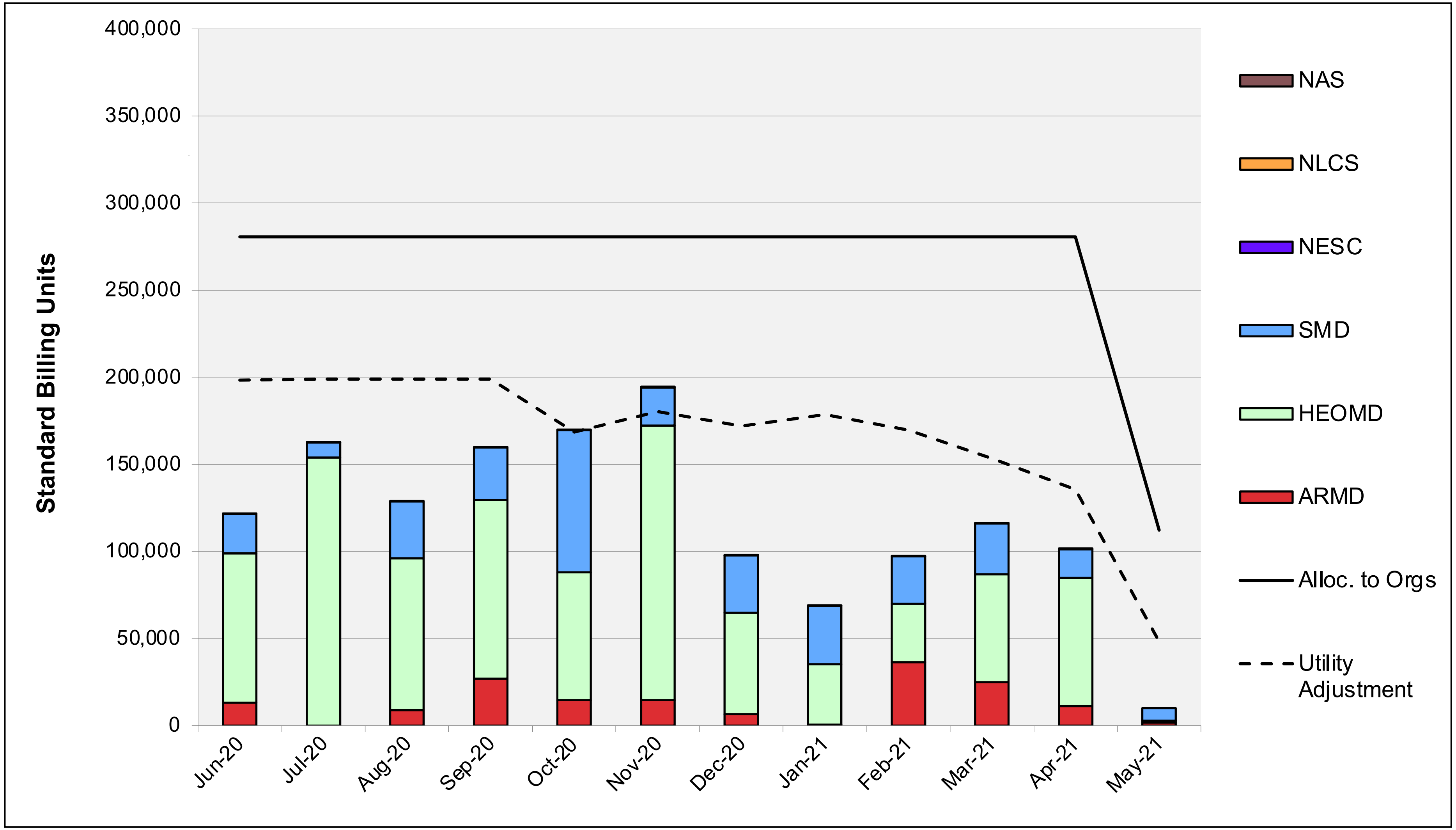
Electra: Average Time to Clear All Jobs



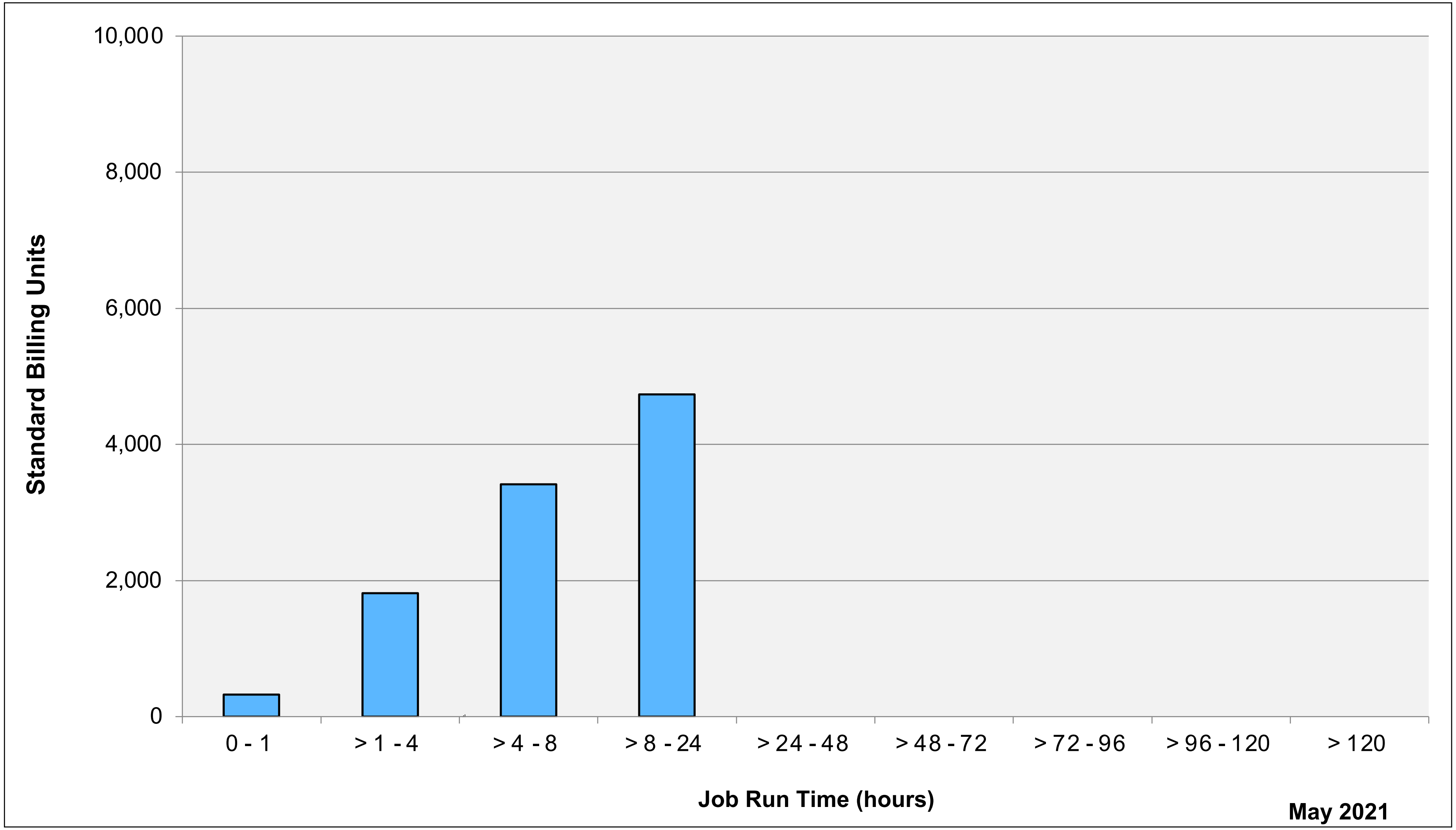
Electra: Average Expansion Factor



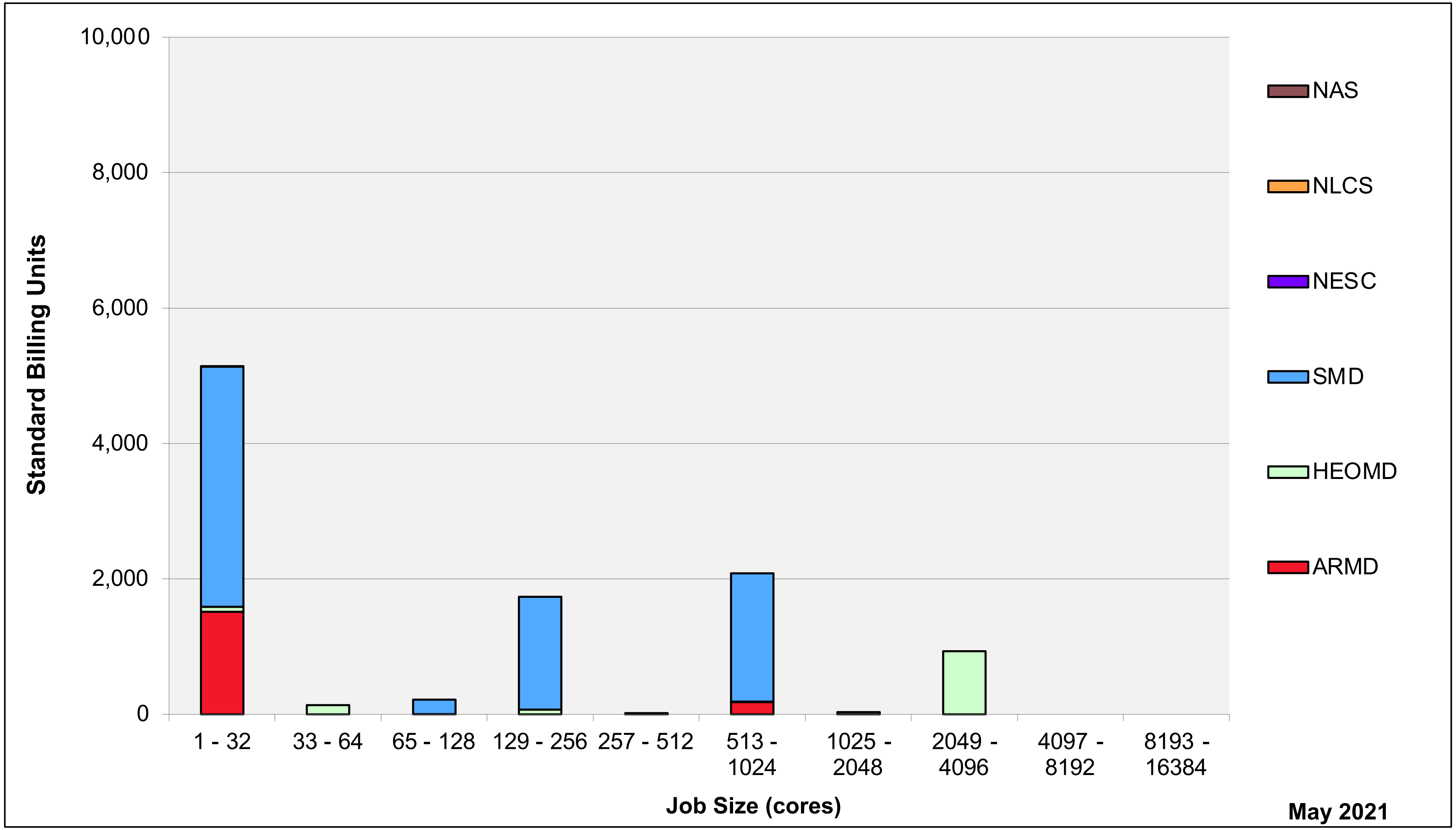
Merope: SBUs Reported, Normalized to 30-Day Month



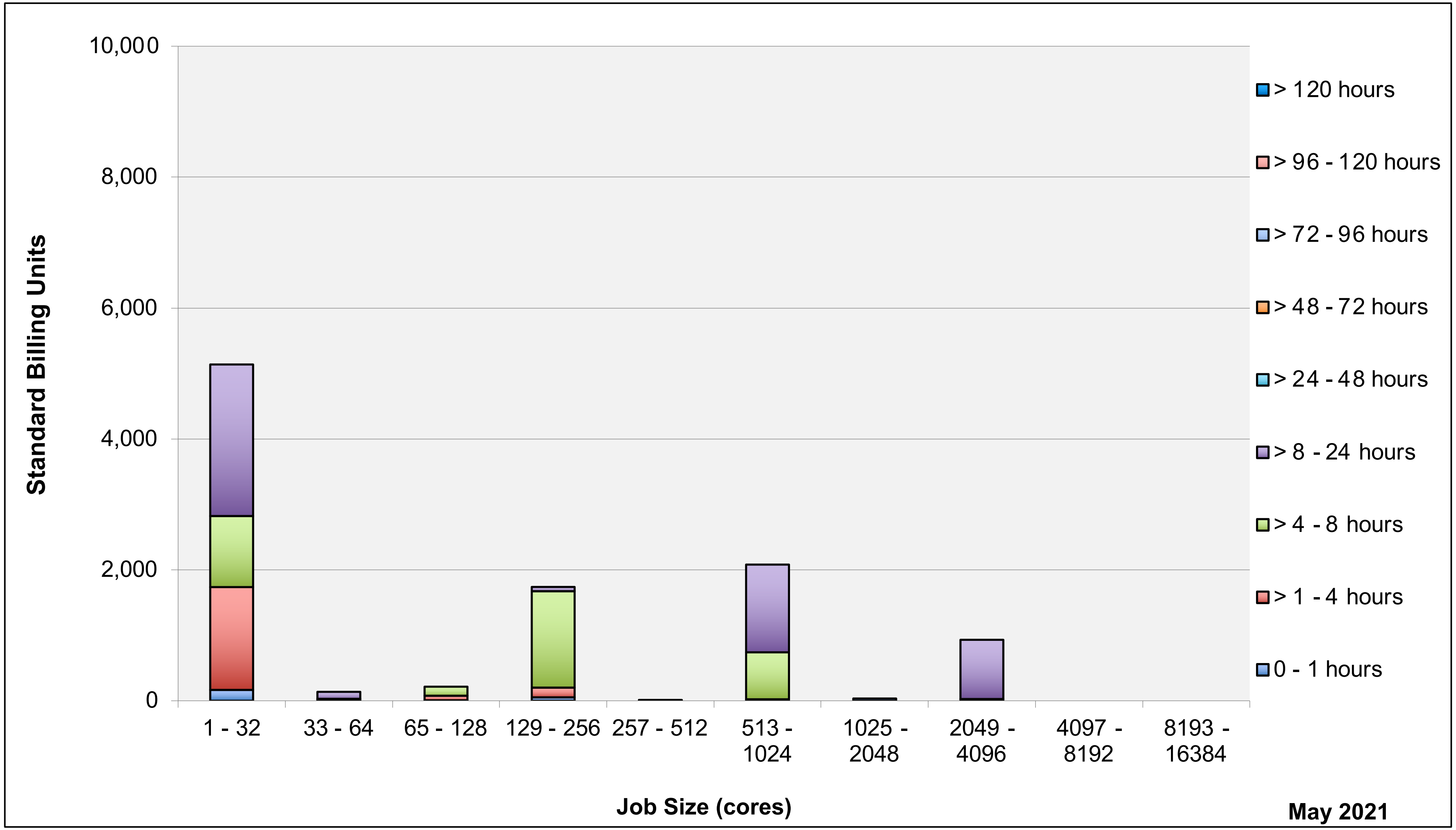
Merope: Monthly Utilization by Job Length



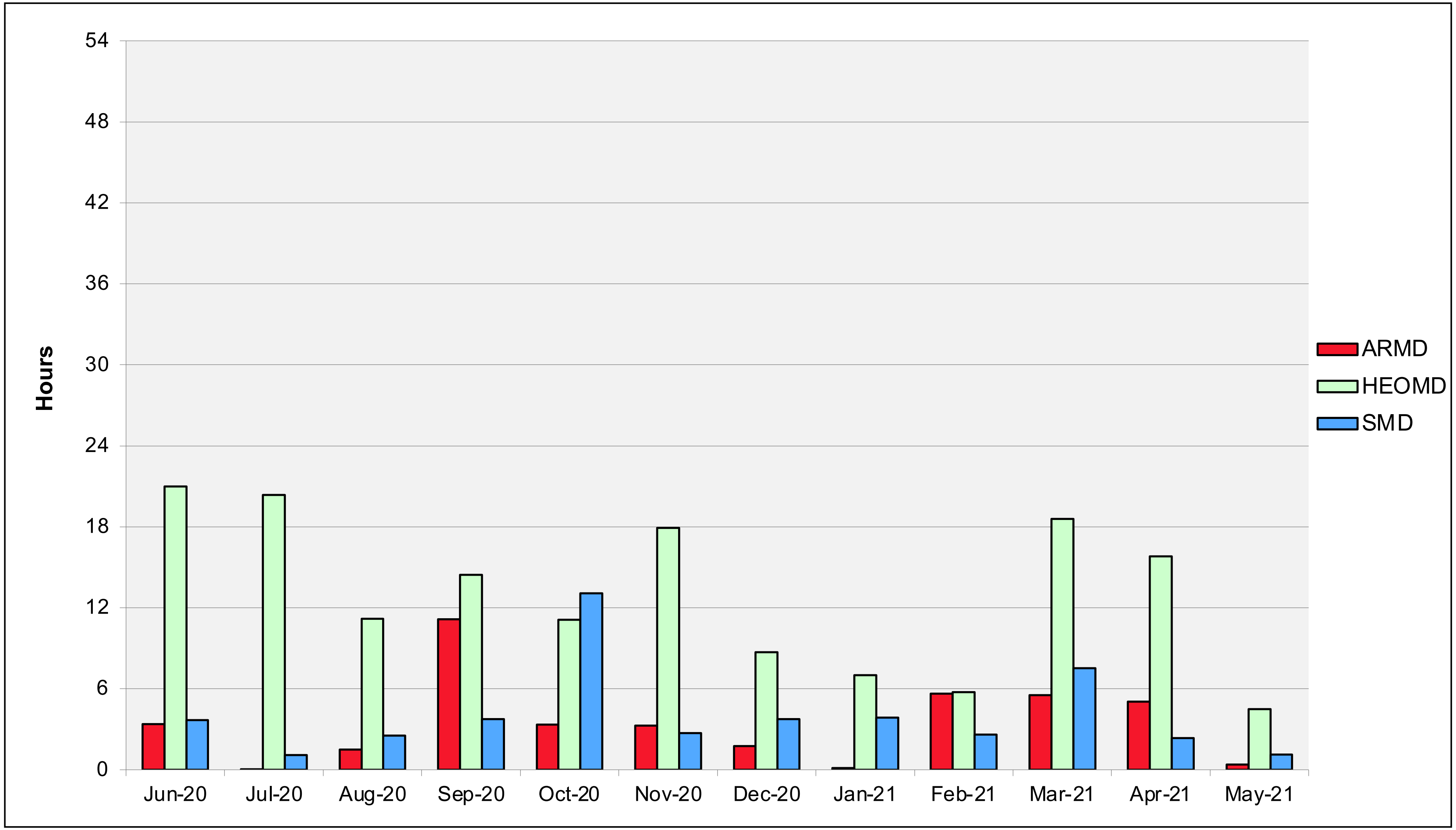
Merope: Monthly Utilization by Job Size



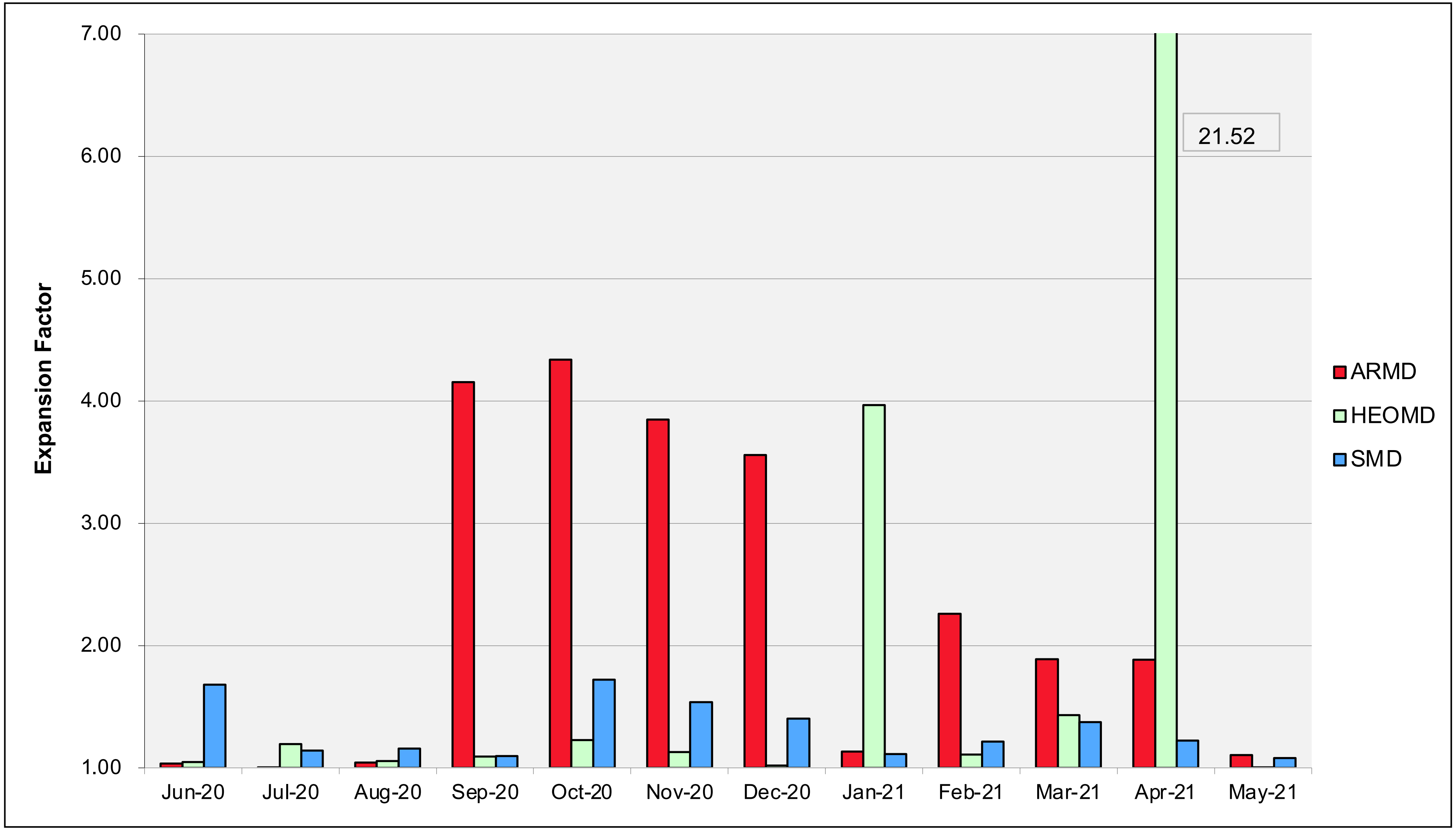
Merope: Monthly Utilization by Size and Length



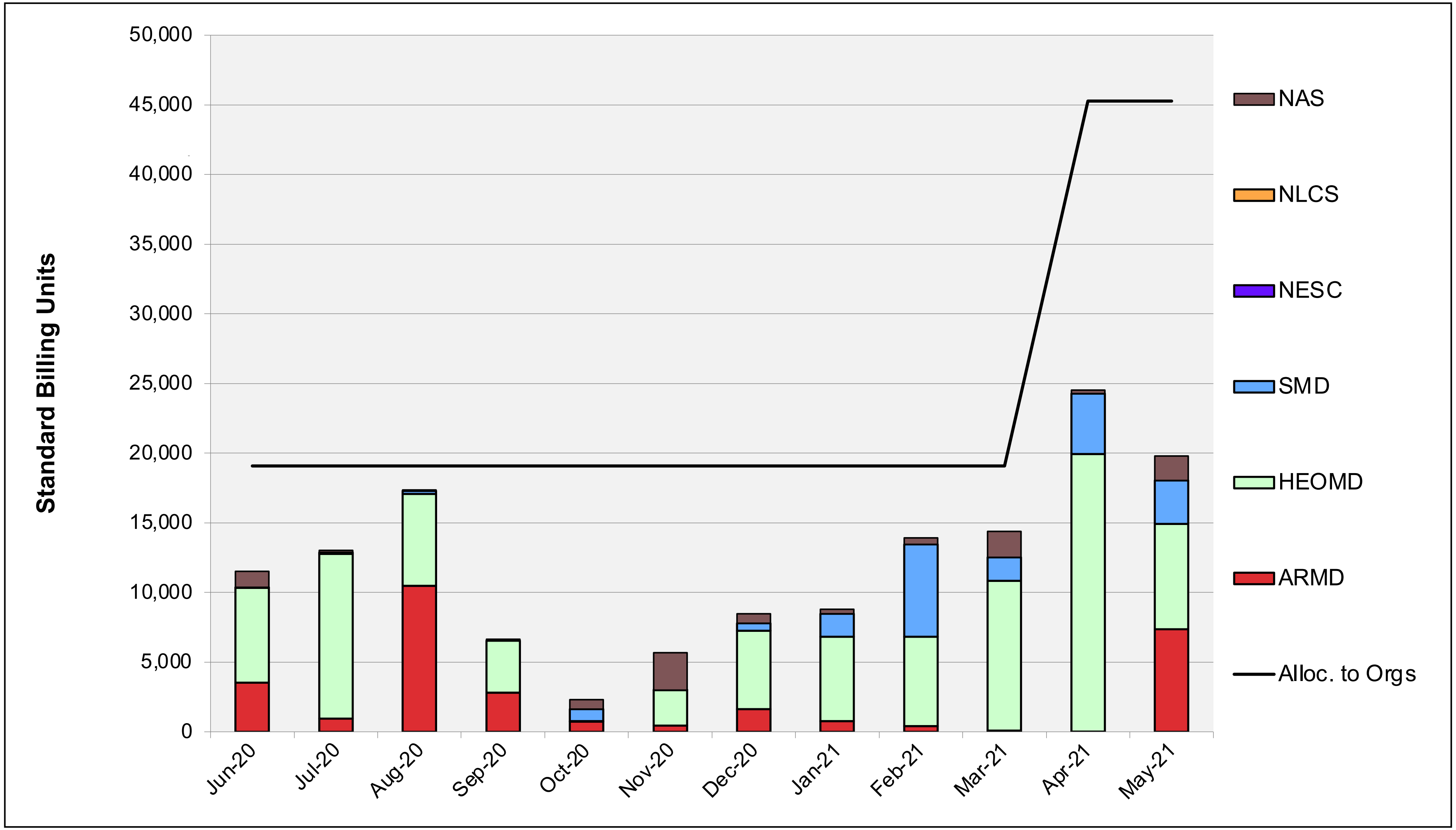
Merope: Average Time to Clear All Jobs



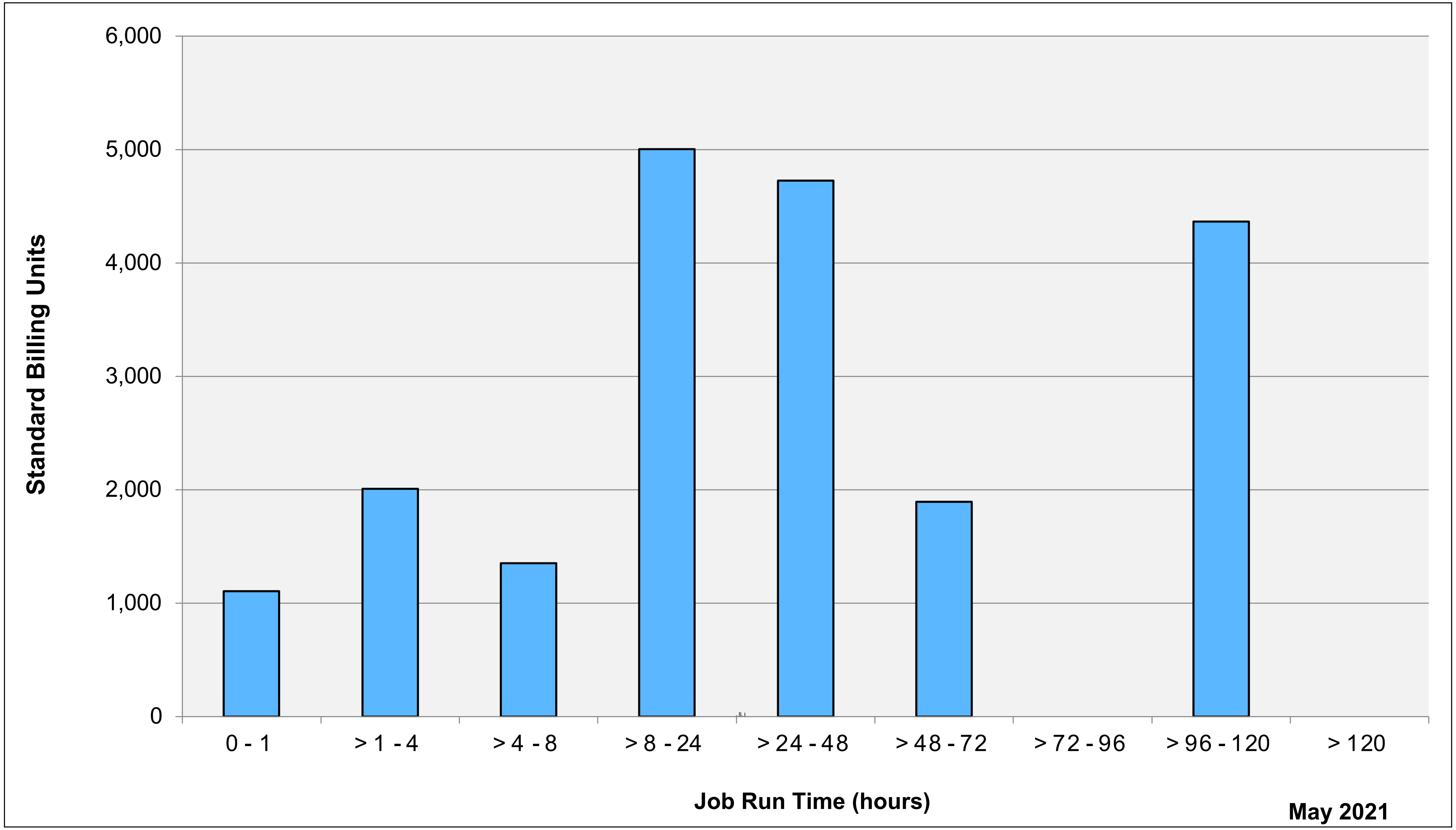
Merope: Average Expansion Factor



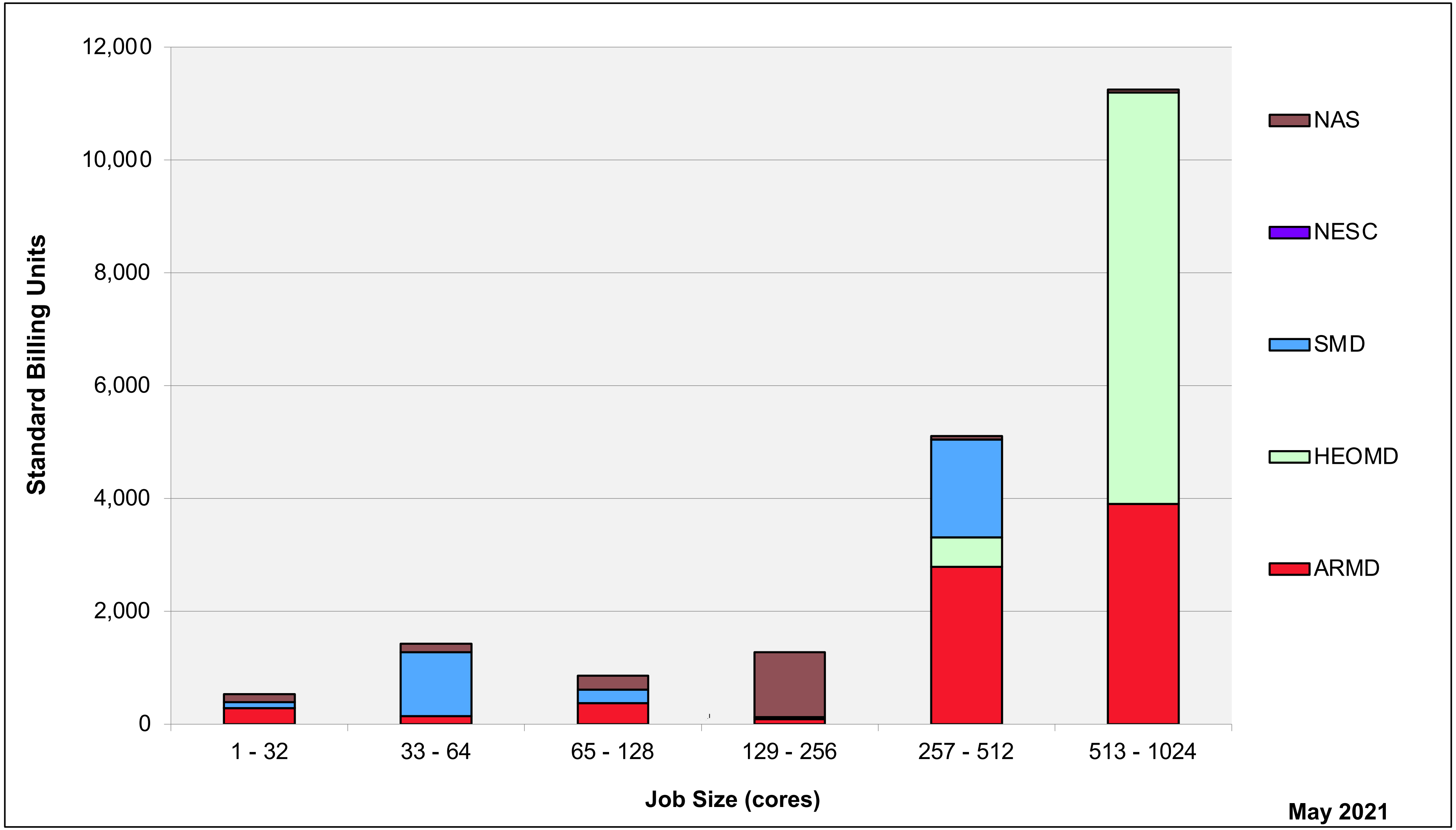
Endeavour: SBUs Reported, Normalized to 30-Day Month



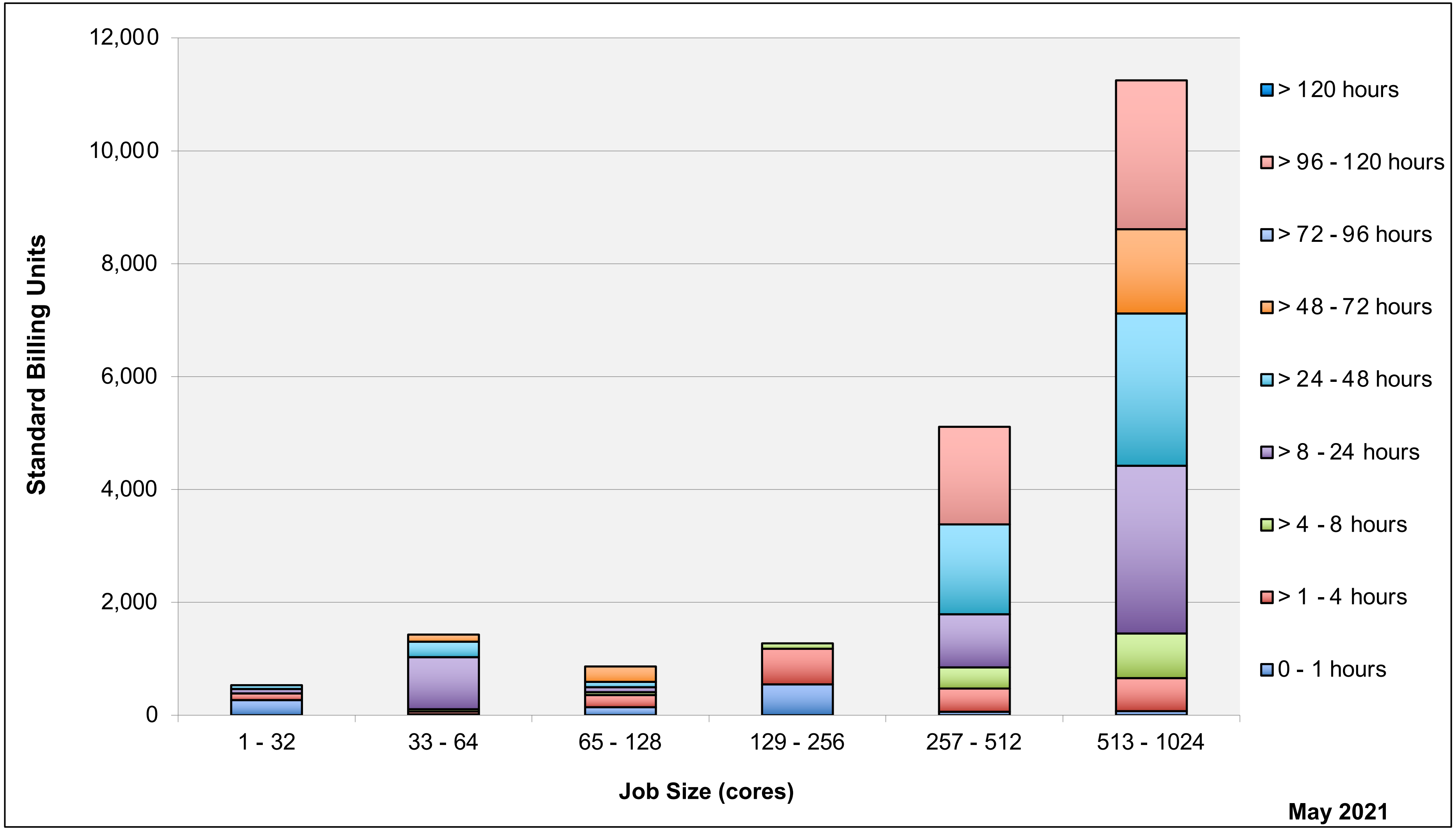
Endeavour: Monthly Utilization by Job Length



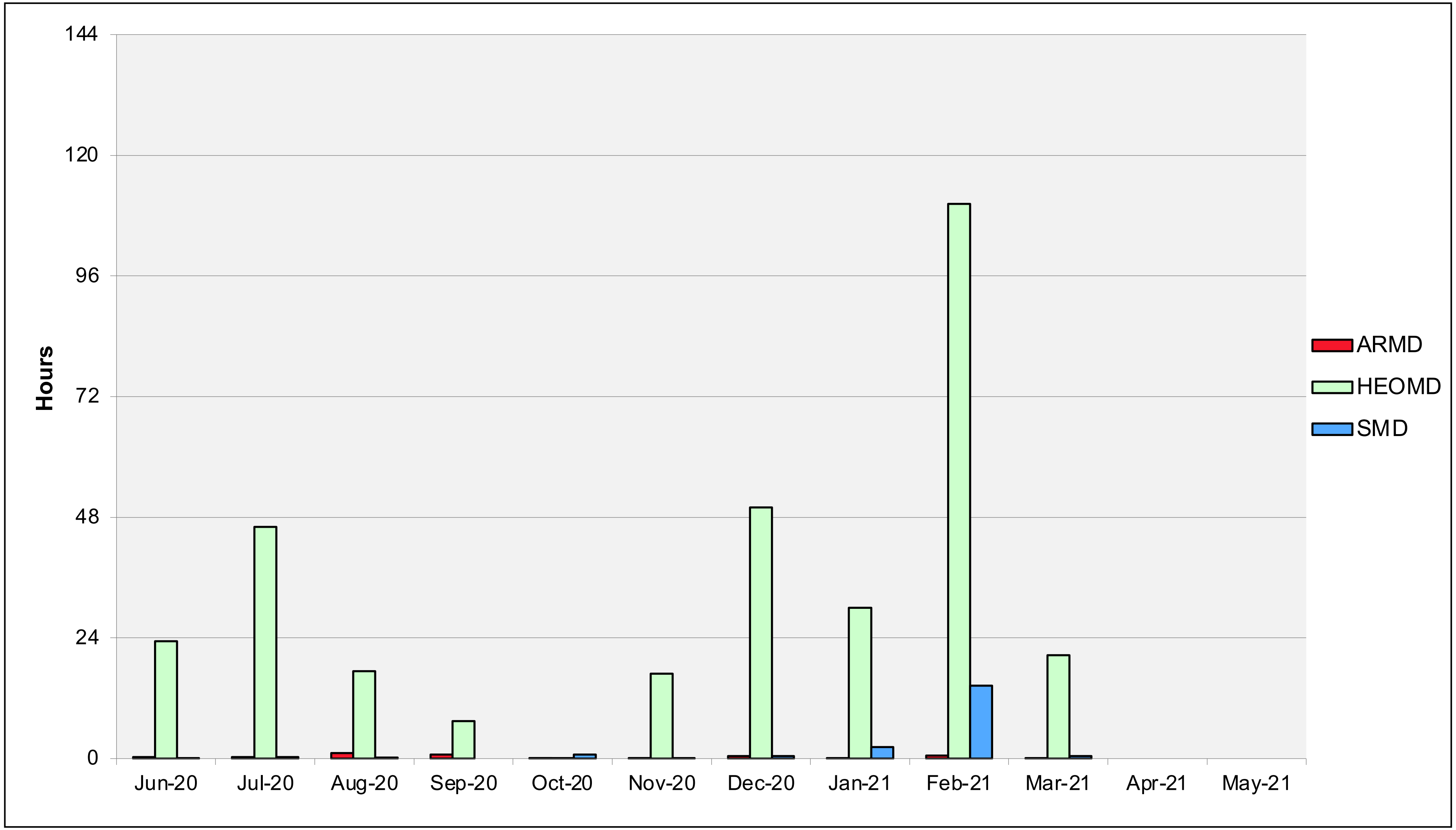
Endeavour: Monthly Utilization by Job Size



Endeavour: Monthly Utilization by Size and Length



Endeavour: Average Time to Clear All Jobs



Endeavour: Average Expansion Factor